Crop Response to Phosphate stemming from Mineral Fertiliser and Organic Waste

Albrecht Siegenthaler[1], Werner Stauffer[2] and Heinz Häni[3]
[1]Im Moesli, CH-3111 Taegertschi-Berne, Switzerland, e-mail: alsigi@bluewin.ch
[2]Swiss Research Station Agroscope Reckenholz-Tänikon,
CH-3003 Berne-Liebefeld, Switzerland, e-mail: werner.stauffer@art.admin.ch
[3]Seidenweg 52, 3012 Berne

Abstract

The aim of this work is to determine the Phosphate- (P) efficiency of sewage sludge compared with mineral P-fertilisers, such as super phosphate or basic slag (Thomas phosphate) for carefully and efficiently phosphate use as possible.

Presented are the results of crop yield and P-uptake of two field experiments (52 x 162 meter) using two different soils that are poor in phosphate over eight years. The following treatments, each in four repetitions, were compared: zero-P-, P-mineral fertiliser- and P-plots where the sludge originated from six different sewage sludge plants (two without- and four with P-elimination). The cultivated crops that were planted in a simple crop rotation were silage maize, grass-clover mixture and an alternation between sugar beet and potatoes.

The calculated P-efficiency of sewage sludge, compared with commercial fertilisers, varied between 53% – 100% (plant yield) and 49% – 97% (nutrient uptake). Due to the risks of heavy metals, harmful organic compounds and pathogens, the agricultural use of sewage sludge is for instant prohibited in Switzerland

Key words: phosphate efficiency, P-uptake, field experiments, mineral P-fertiliser, sewage sludge, crop yields

Introduction

This work aims at determining the P-efficiency of sewage sludge compared with mineral P-fertilisers, such as super phosphate or basic slag (Thomas phosphate) for different crops under field conditions.

The present data serve as a basis for discussing the:

- Scientific understanding of P-reactions in soils,
- Plant P-uptake,
- Crop response to sewage sludge phosphate,
- Prediction of necessary P-fertiliser application and the
- Management of P-fertilisers in plant production.

The main objective is a careful and efficient use of the limited existing phosphate

The Field Experiments

Over eight years crop yield and nutrient uptake were measured in two field experiments (52 x 162 meter) near Berne (Switzerland) on phosphate poor soils and different pH-values with several crops (silage maize, grass-clover mixture, sugar beet, potatoes) in rotation with nine treatments and four repetitions.

The Experimental Fields (soil description at start of experiment)

Location:	Herzwil	Oensingen
pH-value (water)	5.7 acid	6.8 neutral
Phosphate content*	4.9* poor	3.0* poor
Organic matter %	2.6	3.9
Clay %	18	35
Silt %	30	38
$CaCO_3$ %	0	0.3
Stone %	19.8	23.0
Soil type	acid compact brown earth	para brown earth

*(extracted with CO_2-saturated water, 1 : 2.5)

Climatic Conditions

Annual precipitation: 860 - 1360 mm

Average temperature: 7° - 9° C

Average summer temperature (April - October): 12.1° - 16.9° C

Applied Fertilisers

Organic waste:

Six different sewage sludge's: two without P-elimination (A), three with Fe-P-elimination (B) and one with Al-P-elimination (C) with the following characteristics:

	P (total kg/t DM)	pH-value	dry matter (%)
A	29.3 - 36.5	7.3 - 7.4	5.3 - 5.7
B	34.1 - 36.9	7.3 - 7.5	7.1 - 9.6
C	49.9	7.4	4.3

Mineral fertiliser (as comparison)

Super phosphate and basic slag	P (total %)	P (soluble in water/citric acid %)
Superphosphate	8.5 (8.4 - 8.6)	7.5 (7.3 - 8.0)
Basic slag	7.5 (6.9 - 8.9)	6.0 (5.7- 6.2)

Results

The pH values for the control plots at both locations decreased slightly. Fertiliser application had no statistically significant influence on the soil pH. The yield from P-fertilised soils was always higher than from those without fertiliser application. In some cases the difference was statistically significant. The yields corresponded to a good average Swiss harvest (Table 1).

The comparison of relative yields on unfertilized and P-fertilised plots (P-fertilised plots = 100%) by different crops is shown in table 1. The best efficiency of sewage sludge – P results for potatoes.

P-efficiency (Table 2) of sewage sludge, compared with commercial fertilisers -basic slag in acid soil and superphosphate in neutral soil varied between 53% – 100% related to plant yield and 49% – 97% regarding the nutrient uptake. Sugar beet has in both soils the best P-acquisition capacity.

The best results were measured for crops that had been treated with waste water sludge without P-elimination. The lowest P-efficiency was observed for sewage sludge that had been treated with chemicals for precipitating aluminium sulphate. In our experiments, the application of sewage sludge as a P-substitute positively affected plant growth and, therefore, plant yield.

Table 1. Relative yield in t/ha of several crops for plots with mineral fertiliser application [absolute yield of plots with P-fertilizer]

Treatments	Silage maize (whole plants)	Grass-clover	Sugar beet	Potatoes
Acid soil, unfertilized (0-plot)	87.9*	83.4***	87.0*	90.7
½ P	94.8	94.8	99.0	102.1
P	100	100	100	100
total yield t/ha	[17.22]	[12.58]	[10.78]	[32.55]
Neutral soil, unfertilised (0-plot)	96.7	93.7*	94.5	79.0***
½ P	100.2	98.9	102.9	92.3
P	100	100	100	100
total yield t/ha	[16.66]	[13.04]	[12.41]	[34.17]

* statistically significant difference for P = 0.05
***statistically significant difference for P = 0.01

Table 2. Calculated average P-efficiency[1] of sewage sludge in % with respect to yield and P-uptake[2]

Soil type	Silage maize	Grass-clover	Sugar beet	Potatoes
Acid soil, Yield	66	81	98	100
P-uptake[2]	53	87	97	55
Neutral soil, Yield	53	97	96	64
P-uptake[2]	49	87	97	55

[1] P-efficiency = 100 (Yield of sewage sludge fertilised plot – zero plot) / (Yield of mineral P fertilised plot – zero plot)

$$\text{P-efficiency} = \frac{100\,(\text{Yield of sewage sludge fertilised plot} - \text{zero plot})}{(\text{Yield of mineral P fertilised plot} - \text{zero plot})}$$

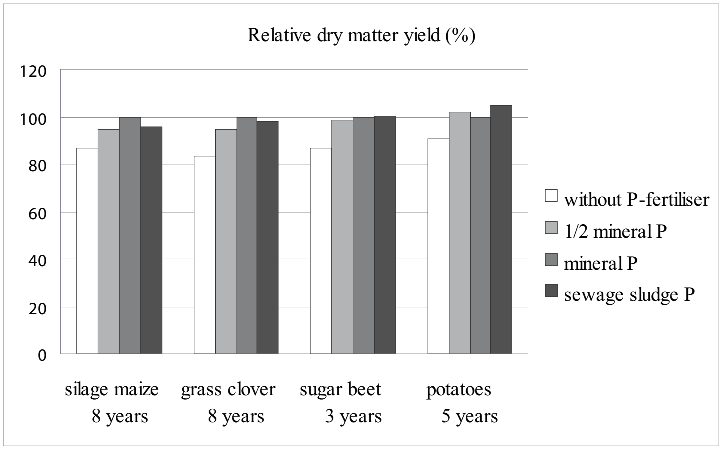
[2] P-uptake = Yield x P-content of the appropriate culture)

Conclusions

P-efficiency of sewage sludge, compared with commercial fertilisers (basic slag and superphosphate), varied between 53% – 100% (plant yield) and 49% – 97% (nutrient uptake).

The application of sewage sludge in agriculture is only feasible if heavy metals, harmful organic compounds and pathogens are limited and controlled. Due to those risks, the agricultural use of sewage is currently prohibited in Switzerland.

Figure 1. Relative yield of unfertilised-, mineral- and sewage sludge P-fertilised crops (P = 100 %) over eight years



Acknowledgements

The authors would like to thank:
Our Co-workers at Liebefeld Research Station for their assistance on this subject over many years, especially Dr. Peter Lischer for the statistical analysis of data's,
Mrs. Maria Atkinson-Bernhard, Harrogate, UK for improving the English style of the manuscript.

References

Häni H., Siegenthaler A. and Candinas T. 1996: Soil effects due to sewage sludge application in agriculture. Fertilizer Research, 43, 149-156.

Morel C., 2004: Biodisponibilité du phosphore dans les sols agricoles, Identification, caractérisation et évolution, COVAPHOS I, Marrakech.

Siegenthaler Albrecht, 1990: Wirkung von Klärschlamm- und Handelsdüngerphosphat auf Ertrag und Nährstoffgehalt von Pflanzen und Böden in unterschiedlichen Boden-pH-Bereichen. Diss. ETH Nr. 9075, Zürich, Switzerland.

Siegenthaler Albrecht, Stauffer Werner and Heinz Häni 2006: Phosphate Efficiency for a Sustainable Plant Production, Recherphos, COVAPHOS II, November, 09-11, Marrakech, Morocco.