# INVESTIGATIONS INTO THE USE OF SEWAGE SLUDGE AS A SOIL AMENDMENT FOR SUGARCANE

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## Abstract

Treated sewage sludge was tested as a source of nutrients and as a nematicide for sugarcane on a weak sandy soil at La Mercy. The sewage sludge was applied at rates of 7, 14, 28 and 200 tons per hectare to the plant crop only. Inorganic fertilizers at the standard rate and half the standard rate were applied to the plant crop and to each of three ratoons. The sucrose yield responses to application of sludge in the plant crop and residual effects in the ratoon crops were measured. Although plots treated with the standard inorganic fertilizer yielded more than all sludge treatments in the plant crop, there was an indication of a rate response to sewage sludge. Plots that had received 200 tons per hectare produced the highest sucrose yields in the first and second ratoons, but not the third ratoon crop. One observation plot without nematicide indicated that the sewage sludge could not substitute for a nematicide on this soil.


## Introduction

The problem of final disposal of treated sewage sludge is becoming more difficult because of population and industrial growth. In 1983 the Durban Municipality initiated an experiment to test the merits of sewage sludge as a soil amendment for the cultivation of sugarcane. Encouraging results were obtained, indicating that some nutritional qualities of the sludge were able to be exploited by the sugarcane crop (Easton *et al.*, 1985). As a result it was suggested that a field experiment be established to quantify these benefits further, and to consider the feasibility of commercial use of the product.

Analysis of the treated sludge indicated that this material contained reasonable amounts of plant available nitrogen and phosphorus but little potassium, as shown in Table 1.

## Methods

A site for the experiment was selected at the La Mercy farm of the SASA Experiment Station situated on the Natal north coast. The soil was of the Fernwood form and the physical and chemical analysis of the topsoil (0–250 mm) is shown in Table 2.

Treatments chosen for the experiment are shown below.

1. Fertilizer at the normal rates recommended by the Fertilizer Advisory Service (FAS) of the SASA Experiment Station, but with the level of nitrogen decreased by half.
2. As for the previous treatment but with the full rate of nitrogen fertilizer.
3. Sewage sludge at a rate of 7 t/ha (74,5% moisture).
4. Sewage sludge at the rate of 14 t/ha.
5. Sewage sludge at the rate of 28 t/ha.
6. Sewage sludge at the rate of 200 t/ha.

Sewage sludge rates were selected so that 14 t/ha would supply the same nitrogen rate as the full FAS treatment. Likewise in treatment 3, extra phosphorus and potassium were applied to match the levels applied in treatments 1 and 2 and to take into account the amounts supplied in the sewage sludge. In treatments 4, 5 and 6 extra potassium only was applied as the quantity of phosphorus in the sewage sludge was sufficient. These rates were chosen based on the analysis of a sludge sample supplied well before the trial was established. However, analysis of the sludge used was different (see Table 1) and therefore the intended equivalent rates were not supplied. Details of actual nutrients applied in the sludge and inorganic form to the plant crop are shown in Table 3. Four observation plots were also treated and the details are shown in Table 3.

In subsequent ratoon crops no extra nitrogen was applied to any of the sewage sludge treatments, but potassium was applied to all treatments. Treatments 1 and 2 received half or the full FAS rate except in the third ratoon where treatment 1 received no nitrogen. Thus residual effects only of the sewage sludge treatments were measured in the ratoon crops.

**Table 1**
**Sewage sludge analysis (% dry matter or ppm)**

| N % | P % | K % | S % | Ca % | Mg % | P CIT* % | MOIST % | C % | Zn ppm | Mn ppm | Cu ppm | Fe ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,48 | 1,55 | 0,35 | 1,05 | 4,45 | 0,62 | 1,31 | 74,5 | 34,44 | 103 | 520 | 388 | 15550 |

* Citric acid soluble phosphorus

**Table 2**
**Physical and chemical analysis of the soil**

| pH | O.M. % | Clay % | Silt % | Fine sand % | Medium sand % | ppm | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | P | K | Ca | Mg | Zn | Al |
| 5.37 | 0.7 | 7 | 3 | 66 | 24 | 29 | 55 | 125 | 27 | 2,1 | 1 |

**Table 3**

**Nutrients applied in sludge (assuming 80% N availability) and as inorganic fertilizer to the plant crop**

| Treatments | Nutrients applied in the furrow (kg/ha) | | | Nutrients applied as topdressing (kg/ha) | | |
|---|---|---|---|---|---|---|
| | N | P | K | N | P | K |
| T1 Nitrogen at half FAS rate | 30 | 10 | | 30 | | 87 |
| T2 Nitrogen at full FAS rate | 60 | 20 | | 60 | | 175 |
| T3 Sewage sludge 7 t/ha | 50 | 23+5* | 6 | | | 170 |
| T4 Sewage sludge 14 t/ha | 99 | 46 | 13 | | | 165 |
| T5 Sewage sludge 28 t/ha | 199 | 92 | 25 | | | 155 |
| T6 Sewage sludge 200 t/ha | 1420 | 660 | 180 | | | 32 |
| Observation plots | | | | | | |
| Sewage sludge 50 t/ha | 355 | 165 | 45 | | | 139 |
| Sewage sludge 100 t/ha | 710 | 330 | 90 | | | 104 |
| Sewage sludge 150 t/ha | 1065 | 495 | 135 | | | 68 |
| Sewage sludge 200 t/ha **No Temik | 1420 | 660 | 180 | | | 32 |

* applied as single superphosphate
** Temik was included in all treatments except this one

The experiment was laid out as an incomplete Latin square design with five replications. Plot size was six rows by 10 m by 1,3 m (1 m at each end and 1 row each side were discounted for measurements of growth and yield). Observation plots were single plots of the same size.

Growth measurements which included population counts and stalk length were conducted at intervals throughout the life of each crop. Population counts were made on one nett row per plot during the crop and all nett rows at harvest. Stalk lengths were measured on 20 randomly selected stalks in the middle two nett rows per plot. Nett plots were harvested and weighed at the end of each crop, and a sample of 12 stalks was taken from each plot for sucrose determinations.

Representative soil samples were taken at the establishment of the experiment and at the harvest of each crop, and analysed for both major and minor nutrients by the FAS laboratories at the SASA Experiment Station. The results were used to determine potential accumulation of nutrients and selected heavy metals such as Copper (Cu), Iron (Fe), Manganese (Mn) and Zinc (Zn) from the use of sludge.

*Experiment procedures*

The field selected was prepared for planting by disc harrowing after the previous crop had been eradicated. Plots were marked and sewage applied to observation plots and those plots which were to receive 200 tons sludge per hectare by a payloader and trailer. The sludge was then spread with hoes. These plots were ploughed to a depth of approximately 300 mm to mix the soil and sludge. The whole trial area was disc harrowed and the furrows drawn. The remaining sludge treatments were applied in the planting furrows and covered with about 30 mm of soil. Untrashed sugarcane stalks of variety N18 were placed in the furrows in a double line and chopped into setts.

Nitrogen in the form of urea was applied to treatments 1 and 2 in two equal applications in the furrow at planting and over the row six weeks later. Phosphorus as single superphosphate (10,5%) was applied to treatments 1, 2 and 3 in the planting furrow. No extra phosphorus was applied in treatments 4 to 6 as that in the sewage sludge was sufficient. Potassium as KCl (50%) was top-dressed at the required rates to treatments 1 and 2 and applied to treatments 3 to 6 at appropriate levels, intended to balance that available in the sludge, based on the original sample analysis.

Aldicarb nematicide (Temik) was applied at the rate of 20 kg per hectare to all plots except one observation plot which received 200 tons sewage sludge per hectare.

Dates of harvest and rainfall data are given in Table 4. A young age at harvest was maintained to avoid the effects of eldana borer damage.

**Table 4**

**Crop dates and rainfall**

| Crop | Dates | | Age (months) | Rainfall (mm) | LTM* |
|---|---|---|---|---|---|
| | Start | Finish | | | |
| Plant | 26/11/86 | 26/11/87 | 12,0 | 798 | 1082 |
| Ratoon 1 | 26/11/87 | 7/11/88 | 11,4 | 1525 | 999 |
| Ratoon 2 | 7/11/88 | 14/11/89 | 12,2 | 1191 | 1121 |
| Ratoon 3 | 14/11/89 | 1/11/90 | 11,6 | 1021 | 1024 |

* Long Term Mean rainfall

**Table 5**

**Sucrose yields in plots treated with sewage sludge or inorganic fertilizers**

| Treatments | | | Sucrose yields (tons/ha) | | | |
|---|---|---|---|---|---|---|
| Plant | Ratoon 1 | Ratoon 2 | Plant | Ratoon 1 | Ratoon 2 | Cumulative yields |
| T1 Urea (½ FAS) | Urea (½ FAS) | Urea (½ FAS) | 13,0 | 12,1 | 6,2 | 31,3 |
| T2 Urea (FAS) | Urea (FAS) | Urea (FAS) | 14,9 | 11,9 | 5,1 | 31,9 |
| T3 Sludge 7 t/ha | Residual | Residual | 12,7 | 10,5 | 4,8 | 28,0 |
| T4 Sludge 14 t/ha | Residual | Residual | 13,3 | 10,2 | 4,4 | 27,9 |
| T5 Sludge 28 t/ha | Residual | Residual | 13,1 | 10,4 | 5,2 | 28,7 |
| T6 Sludge 200 t/ha | Residual | Residual | 13,9 | 12,3 | 5,1 | 31,3 |
| CV% | | | 6,4 | 13,7 | 18,4 | |
| SED ± | | | 0,54 | 0,97 | 0,60 | |
| LSD (5%) | | | 1,16 | 2,08 | 1,25 | |
| Observation plots | | | | | | |
| Sludge 50 t/ha | | | 15,4 | 13,6 | 9,4 | |
| Sludge 100 t/ha | | | 14,8 | 11,9 | 7,8 | |
| Sludge 150 t/ha | | | 13,2 | 13,2 | 9,3 | |
| Sludge 200 t/ha (no nematicide) | | | 5,1 | 3,1 | 3,4 | |

## Results

*Crop yields*

Sucrose yields for the plant crop and the two subsequent ratoons are summarised in Table 5.

In the plant crop there was a clear indication that nitrogen applied at half the FAS recommended rate was inadequate. All rates of sewage sludge, except 200 t/ha, were similar in their effects to the half FAS rate. The 200 t/ha sewage sludge rate, although considerably better than other rates, still yielded less sucrose than did the treatment with the full FAS rate of nitrogen.

In the first and second ratoon crops there were no indications of better yields from the standard FAS rate of inorganic nitrogen (treatment 2), and the residual effects of sewage sludge were relatively poor. The 200 t/ha treatment however, was superior in the first ratoon crop to other sludge treatments, suggesting that this treatment at least had some residual effect.

The second ratoon yields were variable and it was apparent that no sludge treatments were superior to the half or full FAS rates for nitrogen. Yields from the observation plot which received no nematicide but 200 t/ha sludge were considerably lower than those on all other plots, indicating that sewage sludge was not able to act as a nematicide.

*Yield of the third ratoon crop*

Cane and sucrose yields and crop measurements in the third ratoon crop are shown in Table 6.

**Table 6**
**Yields and crop characteristics of the third ratoon crop**

| Treatments | Cane t/ha | Sucrose % cane | Sucrose t/ha | Stalk length (mm) | Stalk popln. (×1000/ha) |
|---|---|---|---|---|---|
| No nitrogen | 24,6 | 15,26 | 3,8 | 1140 | 95 |
| Urea (FAS) | 33,8 | 15,15 | 5,1 | 1250 | 98 |
| Sludge 7 t/ha residual effect | 26,2 | 15,28 | 4,0 | 1140 | 92 |
| Sludge 14 t/ha residual effect | 25,9 | 15,22 | 4,0 | 1120 | 92 |
| Sludge 28 t/ha residual effect | 29,3 | 14,93 | 4,4 | 1150 | 97 |
| Sludge 200 t/ha residual effect | 34,8 | 13,86 | 4,8 | 1230 | 108 |
| CV% | 19,1 | 4,1 | 20,8 | 7,6 | 8,8 |
| SED ± | 3,5 | 0,38 | 0,57 | 56 | 5,4 |
| LSD (0,05) | 7,4 | 0,81 | 1,20 | 118 | 11,3 |

Despite very poor yields in the third ratoon crop, there was a clear indication of a response to nitrogen in terms of cane and sucrose yields. Low rates of sewage sludge were unable to match this response despite a trend towards higher yields with increasing sludge rates. A rate of 200 t/ha of sewage sludge was equal to the standard fertilizer rate in terms of cane yields, but tended to decrease cane quality, which resulted in lower sucrose yields.

*Cane Quality*

The effects of sewage sludge and standard fertilizer on cane quality are shown in Table 7.

**Table 7**
**Effects of standard fertiliser and sewage sludge on cane quality**

| Treatments | Sucrose % cane | | | |
|---|---|---|---|---|
| | Plant | Ratoon 1 | Ratoon 2 | Ratoon 3 |
| Urea (FAS) | 14,15 | 16,24 | 15,26 | 15,15 |
| 200 t/ha Sewage sludge | 13,27 | 15,73 | 13,29 | 13,86 |
| SED ± | 0,37 | 0,29 | 0,53 | 0,38 |
| LSD (0,05) | 0,78 | 0,61 | 1,11 | 0,81 |

It is clear that there was a consistent tendency for sewage sludge to decrease cane quality, which would be expected if nitrogen was available in excess.

*Leaf nutrients*

Third leaf analyses showing N, P and K contents under the different treatments for the plant crop and two subsequent ratoons are summarized in Table 8.

Leaf nutrients also reflected the nitrogen provided by the 200 t/ha sewage sludge treatment. Rates of sludge up to and including 28 t/ha were generally inferior to the half nitrogen treatment and in the third ratoon they were no better than a zero nitrogen treatment, suggesting that residual effects from these treatments had ceased.

High phosphorus content was evident in the leaves of treatments with high rates of sludge in contrast to potassium, which was low in the sludge and showed no accumulation in the leaves.

*Eldana borer*

The effects of sewage sludge on eldana damage are shown in Table 9.

Damage due to eldana was found to be more severe in cane which received high rates of nitrogen or sewage sludge. This tendency continued in all crops, with 200 t/ha sewage sludge showing the highest levels of damage in most crops. This corroborates previous findings that a high rate of nitrogen favours increased damage by eldana (Nuss and Atkinson, 1983).

**Table 8**
**Third leaf % dry matter analysis (four month old cane)**

| Treatments | | | Plant | | | Ratoon 1 | | | Ratoon 2 | | | Ratoon 3 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant | Ratoons 1 & 2 | Ratoon 3 | N | P | K | N | P | K | N | P | K | N | P | K |
| Urea (½ FAS) | Urea (½ FAS) | No N | 2,01 | 0,23 | 1,20 | 2,07 | 0,19 | 1,32 | 1,78 | 0,19 | 1,30 | 1,59 | 0,15 | 1,25 |
| Urea (FAS) | Urea (FAS) | Urea (FAS) | 2,06 | 0,23 | 1,26 | 2,10 | 0,19 | 1,35 | 1,85 | 0,20 | 1,36 | 1,81 | 0,18 | 1,43 |
| Sludge 7 t/ha | Residual | Residual | 2,01 | 0,23 | 1,23 | 2,07 | 0,18 | 1,28 | 1,63 | 0,18 | 1,26 | 1,59 | 0,16 | 1,29 |
| Sludge 14 t/ha | Residual | Residual | 2,01 | 0,23 | 1,18 | 1,99 | 0,18 | 1,30 | 1,62 | 0,19 | 1,27 | 1,57 | 0,16 | 1,26 |
| Sludge 28 t/ha | Residual | Residual | 2,00 | 0,24 | 1,18 | 2,02 | 0,19 | 1,28 | 1,66 | 0,19 | 1,25 | 1,56 | 0,16 | 1,28 |
| Sludge 200 t/ha | Residual | Residual | 2,20 | 0,27 | 1,16 | 2,18 | 0,22 | 1,30 | 1,81 | 0,22 | 1,31 | 1,69 | 0,19 | 1,37 |

**Table 9**

**Eldana damage (% stalks damaged) and eldana number per 100 stalks in ratoon crops**

| Treatments | Ratoon 1 | Ratoon 2 | | Ratoon 3 | |
|---|---|---|---|---|---|
| | % Stalks damaged | E/100 | % Stalks damaged | E/100 | % Stalks damaged |
| Urea (½ FAS) | 32 | 2,3 | 21,5 | 0,1 | 4,2 |
| Urea (FAS) | 52 | 3,6 | 19,1 | 1,2 | 9,6 |
| Sludge 7 t/ha | 29 | 4,2 | 17,6 | 0,0 | 5,6 |
| Sludge 14 t/ha | 31 | 7,9 | 24,0 | 0,0 | 2,8 |
| Sludge 28 t/ha | 39 | 5,7 | 21,1 | 0,8 | 6,0 |
| Sludge 200 t/ha | 48 | 9,1 | 29,6 | 2,0 | 10,9 |
| CV% | | 68,2 | 35,7 | 211,2 | 63,3 |
| SED ± | | 2,36 | 5,0 | 0,91 | 2,6 |

*Soil nutrient status*

The soil phosphorus and potassium status at establishment and after each harvest are shown in Table 10A.

**Table 10A**

**Soil phosphorus and potassium status at establishment and after each harvest**

| Treatments | P(ppm) | | | | | K(ppm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Plant | | Rat 1 | Rat 2 | Rat 3 | Plant | | Rat 1 | Rat 2 | Rat 3 |
| | Start | End | End | End | End | Start | End | End | End | End |
| Urea (FAS) | 32 | 38 | 24 | 24 | 24 | 58 | 33 | 54 | 62 | 37 |
| Sludge 14 t/ha | 32 | 34 | 22 | 24 | 23 | 58 | 35 | 46 | 54 | 36 |
| Sludge 28 t/ha | 32 | 42 | 26 | 31 | 24 | 58 | 31 | 48 | 63 | 38 |
| Sludge 200 t/ha | 32 | 80 | 57 | 63 | 59 | 58 | 26 | 39 | 52 | 39 |

There was a marked increase in soil phosphorus levels due to the high sludge rates, reflecting the high phosphorus content of the sludge.

Soil calcium and magnesium status at establishment and after each harvest is shown in Table 10B.

**Table 10B**

**Soil calcium and magnesium status at establishment and after each harvest**

| Treatments | Ca(ppm) | | | | | Mg(ppm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Plant | | Rat 1 | Rat 2 | Rat 3 | Plant | | Rat 1 | Rat 2 | Rat 3 |
| | Start | End | End | End | End | Start | End | End | End | End |
| Urea (FAS) | 103 | 130 | 73 | 80 | 115 | 25 | 21 | 22 | 21 | 18 |
| Sludge 14 t/ha | 103 | 170 | 89 | 100 | 134 | 25 | 27 | 25 | 23 | 22 |
| Sludge 28 t/ha | 103 | 189 | 87 | 109 | 136 | 25 | 27 | 23 | 25 | 22 |
| Sludge 200 t/ha | 103 | 204 | 119 | 133 | 146 | 25 | 26 | 23 | 22 | 21 |

The high calcium content of the sewage sludge resulted in higher levels in the soil. The magnesium level in the soil was not clearly affected by the sewage sludge rates, although the average magnesium content in the soil was higher at the end of each crop. The changes in soil organic matter during the crop cycle are shown in Table 11.

**Table 11**

**Soil organic matter changes from planting to the end of the first ratoon**

| Treatments | OM% | | |
|---|---|---|---|
| | Plant | | Ratoon 1 |
| | Start | End | End |
| Urea (FAS) | 0,65 | 0,51 | 0,54 |
| Sludge 14 t/ha | 0,65 | 0,61 | 0,52 |
| Sludge 28 t/ha | 0,65 | 0,61 | 0,59 |
| Sludge 200 t/ha | 0,65 | 0,82 | 0,59 |

Soil organic matter was increased very slightly by sewage sludge treatments, but this effect was no longer apparent at the end of the first ratoon crop. In terms of the heavy metals there was no indication from the analytical results (see Table 12) of any serious accumulation in either Cu, Fe, Zn or Mn levels.

**Table 12**

**Change in heavy metal status in the soil from planting to the end of the third ratoon**

| Treatments | Cu (ppm) | | Mn (ppm) | | Fe (ppm) | | Zn (ppm) | |
|---|---|---|---|---|---|---|---|---|
| | Start | End | Start | End | Start | End | Start | End |
| Urea (FAS) | 2 | 1 | 37 | 14 | 168 | 100 | 1 | 3,0 |
| Sludge 7 t/ha | 2 | 2 | 37 | 18 | 168 | 121 | 1 | 3,1 |
| Sludge 28 t/ha | 2 | 5 | 37 | 19 | 168 | 196 | 1 | 4,7 |
| Sludge 200 t/ha | 2 | 4 | 37 | 14 | 168 | 200 | 1 | 10,7 |
| Toxic level | 1000 | | - | | - | | 3000 | |

## Conclusions

Sewage sludge was able to provide nitrogen and phosphorus to the sugarcane crops over an extended period, as a substitute for repeated applications of inorganic fertilizer. However, rates below and including 28 t/ha of sewage sludge were not sufficient to produce the same yields as those obtained from the standard fertilizer treatment, and 200 t/ha had a negative effect on cane quality. Thus a suitable rate of sewage sludge is likely to be between these rates. Considerable work would be required to establish suitable rates for various soils and to determine the economic value.

Sewage sludge was not able to substitute for a nematicide on these weak sandy soils.

There was a slight accumulation of Cu, Fe and Zn in the soil as a result of the application of sewage sludge. However, the build-up was small, implying that the environmental pollution potential from these elements would be minimal. The heavy metals such as chromium, nickel, lead and cadmium were not monitored in this study, but evidence presented by Easton (1983) implied that cadmium could pose a potential hazard to the environment with continual use of sludge. Easton (personal communication) subsequently considered that limits set in South Africa would not be exceeded by a single application of 200 t/ha (wet mass). However, any further field work with sludge should make provision for determining the rate of cadmium accumulation.

In view of the negative effect of sewage sludge on cane quality any future research programme should make provision for the use of a chemical ripener where this is feasible.

Sewage sludge was able to supply a considerable amount of phosphorus to the soil and may be beneficial in phosphorus fixing soils.

For a more comprehensive understanding of the value of this material, trials need to be done on soils which do not require the use of a nematicide, and where long term residual effects could be measured.

Although a ton of treated sludge would have a nutritional value of about R29, transportation costs would be a major consideration in the economics of its use due to the high moisture content.

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