

*CONFIDENTIAL

IMPROVEMENT OF SOIL CONDITIONS

NAS 200 ML

(First completed treatment and test rotations - 1972-79)

SUMMARY

After a three year treatment sequence, improvements in soil condition were measured, particularly in the first of three test crops. Factory waste line and a three year ley were the most effective treatments.

Only potatoes (the third test crop) gave significant yield responses to soil treatments. Increases in yield were given by the FYM and 3 year ley treatments.

OBJECT

To examine the long term effects of certain soil conditioning treatments which are likely to improve the structure of unstable soils such as that at Morley. The effects on the soil at Morley are measured directly by recording various physical characteristics of the soil and in yield.

TREATMENTS

The trial consists of three phases of two blocks each, giving a total of six blocks. Phases entered the trial in three consecutive years (1972, 1973 and 1974) so that each phase is at a different stage of the rotation and the rotation progresses through the trial beginning at Phase I. The 6 year crop rotation is divided up into a treatment sequence of sugar beet and two cereals which is followed by a test sequence of sugar beet, spring barley and potatoes.

The soil conditioning treatments applied to the treatment sequence consist of:-

- A Arable control
- B Arable control (spare plot)
- C Farm yard manure at 50 t/ha applied prior to the sugar beet in year 1 of the treatment sequence and for sugar beet in the test sequence.
- D Factory waste line at 125 t/ha applied prior to the sugar beet in year 1 of the treatment sequence (for the first rotation only).
- E 1 year ley of Italian ryegrass instead of the second cereal in year 3 of the treatment sequence.
- F 3 year ley of perennial ryegrass sown in year 1 of the rotation to stand for the duration of the treatment sequence.

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The cropping and treatments during the first six year rotation of each phase are summarized in the table below.

Rotations and soil conditioning treatments:

Year of Rotation	A & B	C	Treatments D	E	F
1	<u>Treatment Sequence</u> S.Beet	S.Beet +50 t/ha FYM	S.Beet +125 t/ha Factory lime*	S.Beet	Ley(P.R.G.)
2	W.Wheat	W.Wheat	W.Wheat	W.Wheat	Ley(P.R.G.)
3	S.Barley	S.Barley	S.Barley	Ley(I.R.G.)	Ley(P.R.G.)
4	<u>Test Sequence</u> S.Beet	S.Beet +50 t/ha FYM	S.Beet	S.Beet	S.Beet
5	S.Barley	S.Barley	S.Barley	S.Barley	S.Barley
6	Potatoes	Potatoes	Potatoes	Potatoes	Potatoes

*This dressing only applied once, when the experiment started.

The experimental design is such that treatments A-E are sub-plots within an arable main plot, while the 3 year ley is another main plot. In the test rotation the treatment sub-plots are further divided into sub-sub-plots to examine various levels of nitrogen as follows:-

Sugar beet:- Nil, 38, 75, 113, 151, 188 kg N/ha
 Spring barley:- 38, 75, 113, 151 kg N/ha
 Potatoes:- 80, 120, 160, 200, 240, 280 kg N/ha

METHOD

During the treatment sequence, yield and population data of the sugar beet crop and yield and percentage nitrogen in the grain of both winter wheat and spring barley were recorded. Soil samples were taken regularly to monitor the levels of P, K, Mg, organic matter content and pH levels.

In the test sequence of sugar beet, spring barley and potatoes much more detailed measurements of both soil physical data and crop data were made.

In the first year of the test sequence (i.e. sugar beet), a Peerlkamp Structural index score and shear strength assessment were made on the plough prior to drilling. After drilling, shallow soil samples were taken from the seedbed and allowed to dry before being sieved into various size fractions. Sample of soil were also taken to spade

depth for wet sieving analysis of soil stability. Shear vane assessments were made at 0-5 cm, 5-10cm and 10-15 cm and soil samples were also taken at these depths for soil moisture determination.

At harvest assessments of degree of fanginess were made together with measurements of depth of fanginess. Population counts were made and root and sugar yield were also recorded.

In the second year of the test sequence (i.e. spring barley) shear strength assessments were made prior to drilling and Peerlkamp structural assessments were made after drilling. Soil samples were again taken from the seedbed for soil aggregate size distribution assessments. Shear vane assessments were also taken at the depths described for sugar beet. Soil samples were taken for soil stability assessments.

Plant counts were taken after crop establishment and fertile tiller numbers and grains per ear were assessed prior to harvest. At harvest, yield of grain was measured and samples were taken for moisture determination, thousand grain weight and grain nitrogen determination.

In the final year of the test sequence a shear strength determination and Peerlkamp structural assessment were made prior to planting the potatoes. No soil assessments were made after planting because of the land being left in ridges.

After harvest, the potatoes were riddled into various size fractions and an assessment was made of green and diseased tubers. The specific gravity of the tubers was measured by a water submersing technique employed by the P.M.B.. Sub-samples of the 60-80 mm size fraction were taken for later assessment of bruising levels by slicing the individual tubers.

The results of the determinations carried out during the test sequence, as described above, are given in the ensuing RESULTS section, as means over the three phases of the trial. In Appendix I is given the equivalent test sequence data for each phase separately. Appendix II contains the yields during the treatment sequence, meaned over the three phases.

RESULTS

Sugar beet grown in testing sequence

Crop Yield and Measurements

The 3 year mean results are given in the text. Other data are shown in the appendices, as described above.

Soil measurements

Soil condition was normally assessed by physical examination and measurements before and after drilling and again in mid-summer. Samples were taken after drilling for the measurement of the stability of aggregates when wet sieved and soil aggregate size distribution when dried and sieved.

Peerlkamp ST Index pre-drilling

	Arable controls		Treatments				S.E.
			FYM	F.W. line	1 yr ley	3 yr ley	
1975	4.52	4.55	4.55	5.57	5.97	7.22	±0.232
1976	7.15	7.35	6.95	7.50	7.35	8.45	±0.211
1977	6.32	5.95	5.72	6.52	6.57	6.65	±0.320
MEAN	6.00	5.95	5.84	6.53	6.63	7.44	±0.201

The factory waste line and ley treatments improved the Peerlkamp ST Index, with the three year ley being particularly effective. FYM gave no effect that was measurable by this technique.

Shear strength 10-15 cm depth (KN/m²) - pre-drilling

	Arable controls		Treatments				S.E.
			FYM	F.W. line	1 yr ley	3 yr ley	
1975	16.1	15.3	16.6	14.7	12.9	11.4	±0.66
1976	8.3	8.6	8.1	8.4	7.7	7.3	±0.57
1977	14.9	14.5	15.6	15.1	14.5	13.5	±0.79
MEAN	13.1	12.8	13.4	12.7	11.7	10.7	±0.45

The low values in 1976 indicate the friable nature of the soil following the dry winter. The leys gave some indication of improving the soil's ability to resist compaction, especially in the wet winter preceeding the 1975 crop.

Shear strength 0-15 cm depth (KN/m²) post-drilling

	Arable controls		Treatments				S.E.
			FYM	F.W. line	1 yr ley	3 yr ley	
1975	24.3	24.0	24.2	24.7	22.2	23.8	±0.53
1976	21.3	23.0	23.8	21.5	22.1	19.9	±1.22
1977	27.7	25.6	29.7	27.5	23.5	32.3	±3.98
MEAN	24.6	24.2	25.9	24.6	22.6	25.3	

The cultivation and drilling operations had increased soil compaction. Due to the effect of wheelings, errors were greater, so that differences were generally not significant and the high figure for the 3 year ley in 1977 was an anomolous value.

Shear strength 0-15 cm depth (KN/m²) summer

	Arable controls		Treatments				S.E.
			FYM	F.W. lime	1 yr ley	3 yr ley	
1975	59.7	59.6	56.9	53.6	48.5	47.8	+2.66
1976	29.5	31.4	31.7	29.0	28.6	27.6	+1.39
1977	-	-	-	-	-	-	-
MEAN	44.6	45.5	44.3	42.7	38.6	37.7	

By mid-summer, the superior condition of the factory waste lime and ley treatments were again becoming detectable.

Stability by wet sieving % >0.5 mm

	Arable controls		Treatments				S.E.
			FYM	F.W. lime	1 yr ley	3 yr ley	
1975	59.8	90.0	78.0	90.1	89.4	96.7	+7.98
1976	85.1	73.3	79.8	81.7	75.9	90.8	+2.96
1977	19.9	20.2	18.8	22.9	17.2	22.8	+1.24
MEAN	54.9	61.2	58.9	64.9	60.8	70.1	+3.78

The improvements following the lime and ley treatments were significant in 1975 but failed to reach significance in the other years.

% aggregates <4.75 mm - dry sieved

	Arable controls		Treatments				S.E.
			FYM	F.W. lime	1 yr ley	3 yr ley	
1975	45.7	48.2	50.2	53.4	44.7	51.7	+2.46
1976	55.9	53.8	55.9	55.5	60.0	63.7	+2.00
1977	43.2	47.9	47.1	47.8	48.4	45.8	+2.08
MEAN	48.3	50.0	51.1	52.3	51.0	53.7	+1.48

Although the lime and ley treatments tended to give a better proportion of fine aggregates throughout the trial, the differences only reached statistical significance in 1976. Many different aggregate sizes were measured, but the proportion less than 4.75 mm has been found to give the best correlation with crop establishment.

Sugar beet Mean I, II, III

Plant population at harvest '000s/ha

	Nil	30	Nitrogen				MEAN
			75	113	151	188	
<u>Soil Treatment</u>	(±2.46 VI) (±2.09 H)						(±1.56)
Control 0	81.4	80.5	81.3	78.5	77.1	79.9	79.8
Control 1	81.3	79.9	80.3	77.8	77.1	78.1	79.4
FYM 50 t/ha	80.1	81.7	79.1	77.3	78.0	77.0	78.9
FWL 125 t/ha	81.8	80.4	80.8	86.6	78.4	76.6	80.8
1 yr ley	76.4	78.4	79.6	75.7	76.9	77.1	77.4
3 yr ley	73.2	71.0	73.1	72.3	73.1	72.9	72.6
MEAN	79.0	78.7	(±0.85)		76.8	76.9	
Standard error per plot	Main plot = 4.9%, sub plot = 6.5%						

On average over 3 years final plant population at harvest was significantly lower on the three year ley plots than on the other treatments. This was particularly evident in 1975 and was caused by birds which had established their territories on the 3 year leys subsequently grazing these plots more than the surrounding continuous arable treatments. A slight but non-significant loss was observed in 1977 but no differences appeared in 1976.

Sugar beet Mean I, II, III

Yield of sugar t/ha

	Nil	30	Nitrogen				MEAN
			75	113	151	188	
<u>Soil Treatment</u>	(±0.248 VI) (±0.213 H)						(±0.155)
Control 0	6.61	7.07	7.17	7.24	7.21	7.17	7.13
Control 1	6.65	6.91	7.64	7.29	7.65	6.88	7.17
FYM 50 t/ha	6.86	7.06	7.25	7.20	7.58	7.35	7.22
FWL 125 t/ha	6.82	7.02	7.46	7.42	6.88	7.02	7.10
1 yr ley	7.04	7.58	7.52	7.41	7.08	7.28	7.32
3 yr ley	6.81	6.95	7.14	7.04	6.46	6.89	6.88
MEAN	6.80	7.10	(±0.087)		7.14	7.10	
Standard error per plot	Main plot = 5.3%, sub plot = 7.3%						

Sugar yield was lowest on the 3 yr ley plots, but the reduction was due almost entirely to the loss of yield experienced in 1975 as a result of reduced populations.

The maximum yield achieved with each soil treatment was similar in all cases except for the 3 year ley. However this was achieved at different levels of nitrogen varying from 38 kg/ha for the 1 yr ley to 151 kg/ha for the FYM treatment. There were no significant differences between soil treatment means.

Sugar beet Mean I, II, III % of roots slightly & severely fanged

	Nitrogen						MEAN
	Nil	38	75	113	151	188	
<u>Soil Treatment</u>	$(\pm 3.17 \text{ VI})$ $(\pm 2.85 \text{ H})$						(± 1.81)
Control 0	32.4	28.4	31.8	28.3	33.1	30.9	30.8
Control 1	26.0	32.6	33.0	35.0	27.0	33.6	31.2
FYM 50 t/ha	34.0	36.0	38.5	37.7	3.11	38.1	35.9
FWL 125 t/ha	23.6	23.9	26.5	28.2	26.0	27.4	25.9
1 yr ley	27.5	35.4	37.4	31.8	40.4	30.6	33.8
3 yr ley	40.0	44.1	42.4	41.0	35.8	43.2	41.1
<u>MEAN</u>	30.6	33.4	(± 1.17)		32.3	34.0	
Standard error per plot	Main plot = 13.4%, sub plot = 21.1%						

The degree of fanginess was highest with the three yr leys and lowest with the factory waste line. The former effect was observed in all years whilst the latter was evident in 1975 and 1977. Fanginess was greatly reduced following the dry winter of 1975/6 compared with the other seasons.

SPRING BARLEY grown in testing sequence

Soil measurements

Shear strength was measured prior to seedbed preparation and Peerlkamp ST Index assessments were carried out after drilling. Samples were taken from the seedbed for wet and dry sieving.

Shear strength 10-15 cm depth (KN/m²) pre-drilling

	Arable controls		Treatments				S.E.
			FYM	F.W. line	1 yr ley	3 yr ley	
1976	33.1	31.1	35.2	32.0	32.3	35.1	+2.54
1977	17.6	17.5	16.1	18.4	17.2	16.9	+0.64
1978	17.5	14.4	18.2	14.9	17.5	16.4	+1.13
MEAN	22.7	21.0	23.2	21.8	22.3	22.8	+0.90

No differences were detectable by soil shear strength measurements before drilling.

Peerlkamp ST Index - post-drilling

	Arable controls		Treatments				S.E.
			FYM	F.W. line	1 yr ley	3 yr ley	
1976	5.25	5.45	6.10	6.70	5.90	6.85	+0.295
1977	5.52	5.02	4.65	5.97	5.12	5.20	+0.256
1978	5.35	5.51	4.70	5.94	4.49	5.94	+0.585
MEAN	5.38	5.33	5.15	6.20	5.17	6.00	+0.243

After drilling, the benefits of the line and 3 year ley treatments were detected by these measurements. The differences were statistically significant except in 1978.

Stability by wet sieving, % >0.5 mm

	Arable controls		Treatments				S.E.
			FYM	F.W. line	1 yr ley	3 yr ley	
1976	59.6	69.9	72.8	55.0	75.9	76.8	+3.91
1977	19.2	18.3	17.9	22.4	16.2	18.1	+2.00
1978	53.3	56.7	56.5	62.9	57.3	66.8	+6.20
MEAN	44.0	48.3	49.1	46.7	49.8	53.9	+3.65

Although the 3 year ley showed some improvements in 1976 and 1978, these failed to reach statistical significance.

% aggregates < 4.75 mm - dry sieved

	Treatments						S.E.
	Arable controls	FYM	F.W. line	1 yr ley	3 yr ley		
1976	39.0	41.9	38.8	45.1	40.6	42.0	+3.18
1977	34.0	31.1	28.6	36.6	28.8	27.5	+1.02
1978	34.5	33.2	33.5	38.3	32.0	34.6	+1.86
MEAN	35.8	35.4	33.6	40.0	33.8	34.7	+1.18

In the dry sieving tests only the line treatment showed any improvement.

Crop yield and measurements

S. Barley Mean I, II, III

Plants/m²

	Nitrogen				MEAN
	38	75	113	151	
<u>Soil Treatment</u>	(+10.6)				(+5.3)
Control 0	233	259	241	243	244
Control 1	256	252	272	279	265
FYM 50 t/ha	263	236	242	268	252
FWL 125 t/ha	257	273	256	258	261
1 yr ley	254	242	261	272	257
3 yr ley	267	268	278	251	266
MEAN	255	255	258	262	
Standard error per plot	12.3%				

None of the soil treatments or nitrogen rates had any significant effect on plant numbers.

S. Barley Mean I, II, III

Tillers/m²

	Nitrogen				MEAN
	30	75	113	151	
<u>Soil Treatment</u>	(±18.2)				(±9.1)
Control 0	603	727	749	768	712
Control 1	588	703	726	802	705
FYM 50 t/ha	685	720	769	790	741
FWL 125 t/ha	657	702	769	783	728
1 yr ley	693	760	775	786	753
3 yr ley	722	749	761	803	759
MEAN	658	727	758	789	
Standard error per plot	7.5%				

- Both overall and in 1975 and 1977, numbers of fertile tillers were significantly increased by the FYM, 1 year ley and 3 year ley treatments. There was also a progressive increase in fertile tiller numbers with increasing nitrogen rate in each year. At the highest level of nitrogen there were no significant differences in fertile tiller numbers between the various soil treatments, but at the lowest nitrogen level all the soil treatments were significantly better than the arable controls.

S. Barley Mean I, II, III

1000 grain weight (gram)

	Nitrogen				MEAN
	30	75	113	151	
<u>Soil Treatment</u>	(±0.40)				(±0.20)
Control 0	32.9	31.2	30.5	30.1	31.2
Control 1	33.3	31.7	30.9	29.9	31.4
FYM 50 t/ha	31.4	31.0	30.4	29.0	30.5
FWL 125 t/ha	33.3	32.2	30.9	30.1	31.6
1 yr ley	32.6	31.0	30.7	29.4	30.9
3 yr ley	31.2	30.9	30.4	28.4	30.2
MEAN	32.4	31.3	30.6	29.5	
Standard error per plot	3.9%				

Thousand grain weights were significantly lower on the FYM plots and the 3 year ley plots than on the arable controls but these plots had higher grain numbers per ear. This only reached significance on the 3 year ley plots, however.

S. Barley I, II, III

Yield of grain @ 85% t/ha

	Nitrogen				MEAN
	30	75	113	151	
<u>Soil treatment</u>	(+0.084)				(+0.042)
Control 0	4.61	5.10	5.16	5.34	5.05
Control 1	4.46	5.15	5.31	5.26	5.04
FYM 50 t/ha	4.35	5.17	5.31	5.20	5.13
FWL 125 t/ha	4.66	5.11	5.31	5.37	5.11
1 yr ley	4.97	5.53	5.50	5.45	5.36
3 yr ley	5.16	5.30	5.45	5.35	5.32
MEAN	4.79	(+0.034) 5.23	5.34	5.33	
Standard error per plot	4.9%				

Yield of grain was significantly higher after the 1 year ley and 3 year ley treatments than with the other treatments. There was a progressive increase in yield with nitrogen rate to 113 kg/ha. However the optimum varied from year to year and ranged from 75 kg in 1976 to 151 kg in 1977. Optimum yield appeared to be achieved at lower levels with the 1 year ley and 3 year ley than with the other treatments, although in the 3 yr mean there was no significant increase in yield with any treatment above 75 kg N/ha.

RESULTS

Potatoes grown in the testing sequence

Soil measurements

The soil was only examined prior to planting of the potato crop because the ridging made further comparable measurements impossible.

Peerlkamp ST Index - pre-planting

	Arable controls		Treatments				S.E.
	FYM	F.W. line	1 yr ley	3 yr ley			
1977	5.65	6.02	5.42	6.40	5.45	6.15	+0.361
1978	5.30	5.45	5.35	5.90	4.35	5.80	+0.399
1979	5.37	5.30	5.46	6.07	5.05	5.55	+0.430
MEAN	5.61	5.59	5.41	6.12	4.95	5.83	+0.202

Although significant differences did not appear in the individual years, the overall result showed a benefit from the line treatment.

Shear strength 10-15 cm (KN/m²) - pre-drilling

	Arable controls		Treatments				S.E.
			FYM	F.W. line	1 yr ley	3 yr ley	
1977	13.8	15.5	16.3	13.5	15.3	15.0	+0.94
1978	23.2	20.4	20.1	20.5	20.5	20.0	+1.20
1979	16.6	16.8	18.2	16.0	15.2	16.4	+1.48
MEAN	17.9	17.5	18.2	16.7	17.0	17.2	+0.63

Any benefits from the earlier treatments were not sufficient to be detected by shear strength measurements in this, the third test crop.

Stability by wet sieving, % > 0.5 mm

	Arable controls		Treatments				S.E.
			FYM	F.W. line	1 yr ley	3 yr ley	
1977	17.6	16.0	16.3	18.4	16.6	20.3	+1.67
1978	73.1	79.9	67.0	85.5	65.6	78.6	+4.69
1979	-	-	-	-	-	-	-
MEAN	45.4	47.9	41.7	51.9	41.1	49.4	+2.90

The 1978 and the mean figures show the line treatment to be superior to the 1 year ley though not significantly better than the untreated arable plots.

Crop Yield and Measurements

Yields of small and large ware were statistically analysed separately, but the tabulated figures are not given here, to avoid excessive length. The results were as follows:-

None of the soil treatments affected small ware yield (40-60 mm). Increasing levels of nitrogen above 120 kg/ha progressively reduced this size fraction except in 1977 when it had no effect. The large ware fraction (60-80 mm) was significantly higher on the FYM plots when compared with all treatments except the 3 year ley plots. Yields of this fraction increased steadily to 200 kg N and this was significant except in 1979.

Potatoes Mean I, II, III

Ware yield 40-80 mm t/ha

	Nitrogen						MEAN
	00	120	160	200	240	280	
<u>Soil Treatment</u>	$(\pm 1.24 \text{ VI}) (\pm 1.07 \text{ H})$						(± 0.76)
Control 0	33.7	34.5	36.4	36.2	34.7	32.0	34.6
Control 1	32.1	35.4	35.6	33.2	34.5	33.6	34.1
FYM 50 t/ha	36.8	36.2	35.5	36.8	35.2	37.8	36.7
FWL 125 t/ha	31.9	31.8	32.7	31.4	30.2	29.6	31.3
1 yr ley	33.3	34.0	35.2	35.4	34.6	31.3	34.1
3 yr ley	35.2	35.5	34.4	35.2	33.8	36.1	35.1
MEAN	33.9	35.1	35.0	34.7	33.8	33.4	
Standard error per plot	Main plot = 5.4%, sub plot = 7.6%						

Total ware fraction (40-80 mm) was significantly increased by the FYM treatment and significantly reduced by the FWL treatment when compared with the arable controls. Nitrogen rates produced no significant differences.

There was a suggestion that optimum yields were achieved at lower levels of nitrogen with the FYM and 3 year ley treatments than with the controls or FWL.

Potatoes Mean I, II, III

Total Yield t/ha

	Nitrogen						MEAN
	00	120	160	200	240	280	
<u>Soil Treatment</u>	$(\pm 1.26 \text{ VI}) (\pm 1.07 \text{ H})$						(± 0.80)
Control 0	35.9	36.7	38.8	38.9	37.6	34.5	37.1
Control 1	34.5	37.9	38.2	35.4	37.2	36.3	36.6
FYM 50 t/ha	40.1	40.9	38.3	39.7	37.7	41.0	39.6
FWL 125 t/ha	34.0	34.0	34.8	34.1	32.6	32.0	33.6
1 yr ley	35.8	37.8	37.8	38.4	37.1	34.0	36.3
3 yr ley	37.7	38.2	37.7	38.2	37.0	38.9	38.0
MEAN	36.3	37.6	37.6	37.5	36.5	36.1	
Standard error per plot	Main plot = 5.3%, sub plot = 7.1%						

Again, total yield was significantly increased by the FYM treatment and significantly reduced by the FWL treatment.

Potatoes Mean I, II, III

Specific Gravity

	Nitrogen						MEAN
	80	120	160	200	240	280	
<u>Soil Treatment</u>	$(\pm 0.0014 \text{ VI}) (\pm 0.0012 \text{ H})$						(± 0.0009)
Control 0	1.097	1.095	1.095	1.091	1.092	1.093	1.094
Control 1	1.097	1.096	1.095	1.093	1.092	1.093	1.094
FYM 50 t/ha	1.095	1.094	1.093	1.090	1.089	1.089	1.091
FWL 125 t/ha	1.100	1.097	1.096	1.097	1.093	1.095	1.096
1 yr ley	1.094	1.093	1.094	1.092	1.093	1.089	1.093
3 yr ley	1.097	1.096	1.094	1.093	1.094	1.093	1.095
MEAN	1.097	1.095	1.094	1.093	1.092	1.092	(± 0.0005)
Standard error per plot	Main plot = 0.2%, sub plot = 0.3%						

Specific gravity was lowest with the FYM treatment and highest with the FWL. There was a progressive decrease in specific gravity with increasing nitrogen level.

Potatoes Mean I, II, III

% Blackspot bruising

	Nitrogen						MEAN
	80	120	160	200	240	280	
<u>Soil Treatment</u>	$(\pm 2.30 \text{ VI}) (\pm 1.91 \text{ H})$						(± 1.49)
Control 0	8.5	8.7	11.0	15.6	11.7	10.4	11.0
Control 1	15.9	12.3	13.8	12.3	13.0	12.6	13.3
FYM 50 t/ha	7.4	12.1	11.1	8.0	5.0	8.7	8.7
FWL 125 t/ha	15.2	16.1	16.2	19.4	13.4	11.1	15.2
1 yr ley	10.7	13.5	11.6	10.7	11.4	9.5	11.2
3 yr ley	9.4	12.5	14.7	12.6	12.5	10.4	12.0
MEAN	11.2	12.5	13.1	13.1	11.2	10.2	(± 0.73)
Standard error per plot	Main plot = 30.7%, sub plot = 39.3%						

The low level of bruising with the FYM treatment and high level with the FWL coincided with the specific gravity levels.

Conclusions

All phases of this trial have now completed the first six year rotation and the plots are now in the second treatment sequence. Improvements in soil structure have been recorded following the use of a very high rate of application of factory waste line or the use of leys. These improvements were much greater in the first test crop (sugar beet) than later in the test sequence. The one year ley gave a benefit to soil condition for only one year, while the line and three year ley treatments were just detectable in the third year of test cropping.

Yield improvements were often recorded, but these were not always associated with the best soil physical conditions as measured in this trial. The main exceptions were that farmyard manure gave a significant improvement in yield of potatoes although little improvement in soil condition was measured. This was probably due to better availability of nutrients in dry conditions, particularly for the shallow rooted potato crop which showed the greatest responses. The factory waste line gave good soil conditions but the high pH created by this treatment caused pale foliage on the beet and potato crops and resulted in depressed yields. It is thought that these symptoms are the result of an induced mineral deficiency, but this has not yet been positively identified in spite of extensive crop sampling and analysis.

A three year treatment sequence followed by three years of test cropping is a very short period to build up differences in a long term soil conditions trial, but significant differences have already been recorded. Experience in other trials of this type indicate that differences might be very much larger after two or three rotations.

So far, the average result with farmyard manure has been a gain of 2.75 t/ha of potatoes, while the three year ley increased yield by 1.15 t/ha. Other crops were not significantly improved. There was a loss of sugar yield following the three year ley which was attributed to bird damage on small plots and would probably not occur on a commercial scale. The optimum yield was sometimes achieved at a lower level of nitrogen where FIM or leys were used. Although the responses measured so far would not justify a major change in farming policy, if these responses were increased over a longer period the yield improvements could be quite valuable.

J.G.H. G.M.P. D.B.S.

Appendix I - Annual results of Test Sequence

Sugar Beet 1975, on phase I

Plant population at harvest '000s/ha

	Nitrogen						MEAN
	Nil	36	75	113	151	183	
<u>Soil Treatment</u>	(± 4.11 VI) (± 3.69 H)						(± 2.36)
Control 0	58.8	64.6	59.6	61.7	57.9	62.9	60.9
Control 1	62.2	61.2	59.6	57.4	63.9	59.3	60.6
FYM 50 t/ha	59.8	61.5	55.7	56.0	66.3	57.6	59.5
FWL 125 t/ha	60.0	60.5	59.6	63.2	58.6	62.0	61.5
1 yr ley	52.9	62.4	62.9	59.1	55.3	53.1	58.4
3 yr ley	45.7	45.7	45.7	43.1	46.6	47.6	46.6
MEAN	(± 1.50)						
MEAN	56.6	59.3	57.2	58.4	53.1	57.9	
Standard error per plot	Main plots = 5.3%, sub plots = 9.0%						

Sugar Beet 1976, on phase II

Plant population at harvest '000s/ha

	Nitrogen						MEAN
	Nil	36	75	113	151	183	
<u>Soil Treatment</u>	(± 4.04 VI) (± 3.82 H)						(± 2.02)
Control 0	99.0	94.2	100.0	89.2	87.5	93.5	93.9
Control 1	96.7	94.5	97.7	92.2	91.0	91.7	94.0
FYM 50 t/ha	94.7	96.7	97.0	86.7	84.0	92.2	91.9
FWL 125 t/ha	100.2	94.0	96.0	99.2	90.0	91.2	95.1
1 yr ley	95.2	91.0	94.2	92.2	96.7	95.7	94.2
3 yr ley	99.0	95.2	96.2	91.2	91.7	93.0	94.4
MEAN	(± 1.56)						
MEAN	97.5	94.3	96.9	91.8	90.2	92.9	
Standard error per plot	Main plots = 3.0%, sub plots = 5.0%						

Sugar Beet 1977, on phase III

Plant population at harvest '000s/ha

	Nitrogen						MEAN
	Nil	36	75	113	151	183	
<u>Soil Treatment</u>	(± 4.132 VI) (± 3.591 H)						(± 2.515)
Control 0	86.50	82.75	84.25	84.50	86.00	83.25	84.54
Control 1	85.00	84.00	89.75	83.75	76.50	83.25	83.71
FYM 50 t/ha	85.75	87.00	84.75	89.25	83.75	81.25	85.29
FWL 125 t/ha	85.25	86.75	86.75	92.50	86.75	76.50	85.75
1 yr ley	81.00	81.75	81.75	75.75	78.75	77.50	79.42
3 yr ley	75.00	72.00	77.25	77.50	81.00	78.25	76.33
MEAN	(± 1.466)						
MEAN	83.03	82.37	84.08	83.87	82.12	80.00	
Standard error per plot	Main = 4.3%, sub plot = 6.1%						

Sugar Beet 1975, on phase I

% of roots slightly and severely fanged

	Nil	36	Nitrogen				MEAN
			75	113	151	188	
<u>Soil Treatment</u>			(± 5.32 VI)	(± 5.47 H)			(± 1.84)
Control 0	34.1	38.5	43.4	35.7	37.7	31.3	36.3
Control 1	31.6	38.7	49.0	44.3	40.0	48.7	42.1
FYM 50 t/ha	42.6	49.4	51.0	52.0	37.1	43.2	45.9
FWL 125 t/ha	27.5	26.5	37.4	37.6	33.1	40.0	33.7
1 yr ley	32.0	45.7	44.5	43.1	49.0	46.9	43.5
3 yr ley	40.2	54.7	56.3	49.6	38.9	46.2	47.7
MEAN			(± 2.23)				
MEAN	34.7	42.2	46.9	43.8	39.3	42.7	
Standard error per plot	Main plot = 6.2%, sub plot = 18.6%						

Sugar Beet 1976, on phase II

% of roots slightly and severely fanged

	Nil	36	Nitrogen				MEAN
			75	113	151	188	
<u>Soil Treatment</u>			(± 2.56 VI)	(± 2.06 H)			(± 1.74)
Control 0	17.2	14.6	11.4	14.3	17.7	12.5	14.6
Control 1	12.2	10.6	9.7	14.9	14.7	13.6	12.6
FYM 50 t/ha	15.0	13.9	13.9	14.2	13.1	14.7	14.1
FWL 125 t/ha	14.5	15.8	13.8	14.4	14.7	15.9	14.8
1 yr ley	8.1	13.2	18.3	10.3	15.3	9.2	12.4
3 yr ley	20.3	22.5	22.1	16.2	16.8	23.1	20.2
MEAN			(± 0.84)				
MEAN	14.5	15.1	14.9	14.1	15.4	14.8	
Standard error per plot	Main plot = 16.6%, sub plot = 19.7%						

Sugar Beet 1977, on phase III

% of roots slightly and severely fanged

	Nil	36	Nitrogen				MEAN
			75	113	151	188	
<u>Soil Treatment</u>			(± 6.42 VI)	(± 6.46 H)			(± 2.55)
Control 0	45.9	32.2	40.6	34.9	44.1	48.8	41.1
Control 1	34.2	48.5	40.3	45.3	26.2	38.4	38.8
FYM 50 t/ha	44.5	44.6	50.7	47.0	43.2	56.4	47.8
FWL 125 t/ha	28.8	29.5	28.5	32.7	30.3	26.1	29.3
1 yr ley	42.5	47.2	49.3	42.0	56.9	35.6	45.6
3 yr ley	59.6	55.2	48.8	57.1	51.8	60.3	55.5
MEAN			(± 2.64)				
MEAN	42.6	42.9	43.1	43.2	42.1	44.3	
Standard error per plot	Main plot = 8.4%, sub plot = 21.2%						

Sugar Beet 1975, on phase I

Yield of sugar t/ha

	Nitrogen						MEAN
	Nil	36	75	113	151	188	
<u>Soil Treatment</u>	$(\pm 0.409 \text{ VI}) (\pm 0.306 \text{ H})$						(± 0.207)
Control 0	4.46	5.62	5.61	6.57	5.58	6.15	5.66
Control 1	4.97	5.62	6.14	5.99	6.73	5.45	5.92
FYM 50 t/ha	5.22	4.63	5.47	5.94	6.32	6.00	5.63
FWL 125 t/ha	5.52	6.44	6.36	6.53	5.90	6.85	6.35
1 yr ley	5.92	6.32	6.76	6.72	5.33	6.63	6.36
3 yr ley	4.81	4.83	5.73	5.75	4.60	5.79	5.25
MEAN	(± 0.150)						
Standard error per plot	Main plot = 5.0%, sub plot = 9.3%						

Sugar Beet 1976, on phase II

Yield of sugar t/ha

	Nitrogen						MEAN
	Nil	36	75	113	151	188	
<u>Soil Treatment</u>	$(\pm 0.367 \text{ VI}) (\pm 0.340 \text{ H})$						(± 0.197)
Control 0	7.41	7.12	7.49	7.49	7.13	6.75	7.23
Control 1	6.86	6.37	7.26	7.11	7.10	6.56	6.87
FYM 50 t/ha	7.02	7.56	7.03	7.03	7.09	7.36	7.18
FWL 125 t/ha	6.90	6.45	6.87	6.91	6.13	5.77	6.50
1 yr ley	6.80	7.46	7.24	7.21	6.78	6.60	7.01
3 yr ley	7.66	7.11	7.19	7.12	6.80	6.60	7.08
MEAN	(± 0.139)						
Standard error per plot	Main plot = 4.0%, sub plot = 6.9%						

Sugar Beet 1977, on phase III

Yield of sugar t/ha

	Nitrogen						MEAN
	Nil	36	75	113	151	188	
<u>Soil Treatment</u>	$(\pm 0.307 \text{ VI}) (\pm 0.254 \text{ H})$						(± 0.202)
Control 0	7.95	8.48	8.41	8.58	8.93	8.61	8.49
Control 1	8.12	8.74	9.53	8.77	9.12	8.65	8.82
FYM 50 t/ha	8.35	8.98	9.25	8.63	8.84	8.70	8.79
FWL 125 t/ha	8.05	8.19	8.63	8.81	8.61	8.43	8.45
1 yr ley	8.40	8.96	8.55	8.30	8.62	8.60	8.57
3 yr ley	7.96	8.84	8.51	8.27	8.11	8.28	8.33
MEAN	(± 0.104)						
Standard error per plot	Main plot = 3.3%, sub plot = 4.2%						

S. Barley 1976, on phase I

Plants/m²

	30	Nitrogen		151	MEAN
		75	113		
<u>Soil Treatment</u>		(+18.81)			(+9.40)
Control 0	233	278	212	232	240
Control 1	237	234	263	284	254
FYM 50 t/ha	230	226	244	206	249
FWL 125 t/ha	256	303	265	258	272
1 yr ley	231	233	253	246	241
3 yr ley	294	245	231	233	251
<u>MEAN</u>	249	(+7.60)		257	
Standard error per plot	13.0%				

S. Barley 1977, on phase II

Plants/m²

	30	Nitrogen		151	MEAN
		75	113		
<u>Soil Treatment</u>		(+17.9)			(+9.9)
Control 0	249	296	278	237	273
Control 1	273	291	312	324	301
FYM 50 t/ha	341	205	272	286	296
FWL 125 t/ha	272	286	253	293	276
1 yr ley	273	278	239	311	289
3 yr ley	239	296	323	251	290
<u>MEAN</u>	285	(+7.3)		292	
Standard error per plot	10.7%				

S. Barley 1978, on phase III

Plants/m²

	30	Nitrogen		151	MEAN
		75	113		
<u>Soil Treatments</u>		(+18.5)			(+9.3)
Control 0	212	203	232	202	213
Control 1	251	233	241	228	238
FYM 50 t/ha	210	197	211	233	213
FWL 125 t/ha	243	225	251	223	235
1 yr ley	254	215	241	260	243
3 yr ley	218	264	281	268	258
<u>MEAN</u>	231	(+7.6)		237	
Standard error per plot	13.8%				

S. Barley 1976, on phase I

Fertile Tillers/m²

	33	Nitrogen		151	MEAN
		75	113		
<u>Soil Treatment</u>		(± 29.1)			(± 14.6)
Control 0	550	665	697	674	643
Control 1	513	659	673	775	657
FYM 50 t/ha	676	650	714	701	687
FWL 125 t/ha	662	676	740	733	703
1 yr ley	675	679	723	683	691
3 yr ley	639	672	662	702	681
MEAN	629	(± 11.9)		712	
Standard error per plot	7.4%				

S. Barley 1977, on phase II

Fertile Tillers/m²

	33	Nitrogen		151	MEAN
		75	113		
<u>Soil Treatment</u>		(± 32.9)			(± 16.5)
Control 0	593	762	769	819	737
Control 1	577	743	773	826	731
FYM 50 t/ha	680	780	838	864	790
FWL 125 t/ha	651	771	813	843	770
1 yr ley	662	793	812	819	772
3 yr ley	733	810	819	879	812
MEAN	651	(± 13.4)		842	
Standard error per plot	7.4%				

S. Barley 1978, on phase III

Fertile tillers/m²

	33	Nitrogen		151	MEAN
		75	113		
<u>Soil Treatment</u>		(± 31.3)			(± 15.7)
Control 0	652	755	779	811	749
Control 1	669	702	725	807	726
FYM 50 t/ha	699	721	757	806	746
FWL 125 t/ha	659	659	754	767	710
1 yr ley	743	807	789	850	797
3 yr ley	740	765	802	827	783
MEAN	694	(± 12.8)		811	
Standard error per plot	7.2%				

S. Barley 1976, on phase I

Yield of grain @ 85% t/ha

	Nitrogen				MEAN
	38	75	113	151	
<u>Soil Treatment</u>	(± 0.111)				(± 0.056)
Control 0	4.04	4.10	3.71	3.99	3.96
Control 1	3.78	4.05	4.05	3.95	3.95
FYM 50 t/ha	3.79	3.67	3.72	3.49	3.67
FWL 125 t/ha	3.60	4.08	3.66	3.67	3.75
1 yr ley	4.25	4.58	4.32	4.07	4.30
3 yr ley	4.12	4.13	4.05	3.87	4.04
MEAN	(± 0.045)				
	3.93	4.10	3.92	3.84	
Standard error per plot	4.9%				

S. Barley 1977, on phase II

Yield of grain @ 85% t/ha

	Nitrogen				MEAN
	38	75	113	151	
<u>Soil Treatment</u>	(± 0.172)				(± 0.086)
Control 0	5.23	6.19	6.39	6.57	6.09
Control 1	5.05	6.07	6.50	6.49	6.03
FYM 50 t/ha	5.63	6.40	6.72	6.73	6.37
FWL 125 t/ha	5.56	6.31	6.65	6.80	6.33
1 yr ley	5.58	6.53	6.56	6.84	6.38
3 yr ley	5.82	6.31	6.57	6.61	6.33
MEAN	(± 0.070)				
	5.48	6.30	6.57	6.67	
Standard error per plot	4.8%				

S. Barley 1978, on phase III

Yield of grain @ 85% t/ha

	Nitrogen				MEAN
	38	75	113	151	
<u>Soil Treatment</u>	(± 0.130)				(± 0.065)
Control 0	4.56	5.02	5.36	5.46	5.10
Control 1	4.54	5.33	5.36	5.35	5.15
FYM 50 t/ha	5.13	5.43	5.49	5.38	5.36
FWL 125 t/ha	4.82	4.94	5.63	5.63	5.26
1 yr ley	5.09	5.49	5.63	5.44	5.41
3 yr ley	5.54	5.47	5.74	5.56	5.58
MEAN	(± 0.053)				
	4.95	5.28	5.54	5.47	
Standard error per plot	4.3%				

Potatoes 1977, on phase I

Ware Yield 40-80 mm t/ha

	Nitrogen						MEAN
	80	120	160	200	240	280	
<u>Soil Treatment</u>	(± 1.92 VI) (± 1.83 H)						(± 0.95)
Control 0	28.6	30.2	32.2	31.8	34.0	26.2	30.5
Control 1	33.2	33.8	35.3	32.1	34.9	33.6	33.8
FYM 50 t/ha	33.1	37.7	33.3	34.6	35.0	36.0	34.9
FWL 125 t/ha	27.5	27.5	28.2	26.2	25.9	27.9	27.2
1 yr ley	30.9	31.5	37.1	36.3	34.4	29.4	33.3
3 yr ley	30.5	30.1	30.1	30.3	32.9	30.9	30.8
<u>MEAN</u>	(± 0.75)						
	30.6	31.8	32.7	31.9	32.8	30.7	
Standard error per plot	Main plot = 4.2%, sub plot = 0.2%						

Potatoes 1978, on phase II

Ware Yield 40-80 mm t/ha

	Nitrogen						MEAN
	80	120	160	200	240	280	
<u>Soil Treatment</u>	(± 2.10 VI) (± 1.94 H)						(± 1.12)
Control 0	40.6	38.7	42.4	43.2	38.0	37.2	40.0
Control 1	36.4	39.3	38.6	36.7	35.9	37.2	37.4
FYM 50 t/ha	40.5	39.3	41.3	39.5	37.9	42.9	40.2
FWL 125 t/ha	35.7	38.0	36.7	36.0	36.1	35.7	36.4
1 yr ley	36.4	38.1	34.9	36.7	38.7	37.4	37.0
3 yr ley	41.6	41.3	39.9	40.7	37.5	44.5	40.9
<u>MEAN</u>	(± 0.79)						
	38.5	39.1	39.0	38.8	37.3	39.2	
Standard error per plot	Main plot = 4.1%, sub plot = 7.1%						

Potatoes 1979, on phase III

Ware Yield 40-80 mm t/ha

	Nitrogen						MEAN
	80	120	160	200	240	280	
<u>Soil Treatment</u>							
Control 0	31.9	34.8	34.6	33.5	32.1	32.6	33.2
Control 1	26.8	33.1	32.7	30.8	32.7	29.9	31.0
FYM 50 t/ha	36.8	37.6	32.0	36.5	32.7	34.6	35.0
FWL 125 t/ha	32.6	30.1	33.1	32.2	28.5	25.3	30.3
1 yr ley	32.7	34.9	33.7	33.4	30.8	27.3	32.1
3 yr ley	33.6	35.1	33.2	34.8	31.1	32.9	33.5
<u>MEAN</u>	32.4	34.3	33.2	33.5	31.3	30.4	
Standard error per plot	Main plot =						

Standard errors not yet available for Phase III

Potatoes 1977, on phase I

Total Yield t/ha

	Nitrogen						MEAN
	00	120	160	200	240	280	
<u>Soil Treatment</u>	(± 1.91 VI) (± 1.79 H)						(± 0.99)
Control 0	30.1	31.3	33.9	33.7	35.4	27.2	31.9
Control 1	34.5	35.9	37.0	33.5	36.1	35.4	35.4
FYM 50 t/ha	36.1	39.6	34.7	36.4	35.9	37.4	36.7
FWL 125 t/ha	28.6	28.9	28.8	27.6	27.3	28.7	28.3
1 yr ley	32.6	33.7	39.4	38.4	35.7	30.5	35.0
3 yr ley	32.5	31.7	33.0	32.9	35.3	32.6	33.0
MEAN	(± 0.73)						
MEAN	32.4	33.5	34.5	33.8	34.3	32.0	
Standard error per plot	Main plot = 4.2%, sub plot = 7.6%						

Potatoes 1978, on phase II

Total Yield t/ha

	Nitrogen						MEAN
	00	120	160	200	240	280	
<u>Soil Treatment</u>	(± 2.15 VI) (± 2.02 H)						(± 1.10)
Control 0	42.7	41.6	45.6	46.6	41.6	40.2	43.1
Control 1	39.3	42.2	41.9	39.4	40.2	40.8	40.6
FYM 50 t/ha	44.0	42.9	45.4	42.5	40.7	47.1	43.8
FWL 125 t/ha	39.1	40.1	39.7	39.3	39.3	39.2	39.4
1 yr ley	39.2	42.0	37.3	39.8	42.3	41.0	40.3
3 yr ley	45.2	44.5	43.5	42.6	41.1	47.5	44.1
MEAN	(± 0.83)						
MEAN	41.6	42.2	42.3	41.7	40.9	42.6	
Standard error per plot	Main plots = 3.7%, sub plots = 6.8%						

Potatoes 1979, on phase III

Total Yield t/ha

	Nitrogen						MEAN
	00	120	160	200	240	280	
<u>Soil Treatment</u>							
Control 0	34.7	37.3	37.0	36.4	35.7	36.3	36.2
Control 1	29.5	35.7	35.3	33.1	35.3	32.8	33.7
FYM 50 t/ha	40.1	40.3	34.7	40.3	36.5	33.5	38.4
FWL 125 t/ha	34.4	33.2	35.8	35.3	31.2	28.2	33.0
1 yr ley	35.6	37.9	36.3	37.2	33.5	30.5	35.1
3 yr ley	35.6	38.5	36.6	39.2	34.7	36.7	36.9
MEAN							
MEAN	35.0	37.2	36.0	36.9	34.5	33.8	
Standard error per plot	Main plot =						

Standard errors not yet available for Phase III

Appendix II

TREATMENT CROPPING Means over the 3 phases

	SUGAR BEET		WINTER WHEAT		SPRING BARLEY	
	YIELD OF SUGAR t/ha	POPULATION MT HARVEST t/ha	YIELD OF GRAIN t/ha	% N in grain %	YIELD OF GRAIN t/ha	% N in grain %
<u>Soil Treatment</u>						
Control 0	6.55	70.0	5.71	2.09	4.56	1.99
Control 1	6.78	73.6	5.61	2.03	4.48	1.97
FYM 50 t/ha	6.81	77.4	5.81	2.19	4.70	1.99
FWL 125 t/ha	6.98	74.6	6.03	2.04	5.13	2.01
1 yr ley	6.69	71.5	5.77	2.04	-	-
	± 0.152	± 2.60	± 0.243	± 0.027	± 0.132	± 0.023
Standard error per plot	5.5%	8.7%	10.3%	3.2%	6.8%	2.8%