

## THE EFFECTS OF SOIL STERILISATION WITH STEAM-AIR MIXTURES ON THE DEVELOPMENT OF SOME GLASSHOUSE CROPS

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### SUMMARY

The undesirable side effects in lettuce crops grown on soils sterilised at 100°C, do not occur on soils sterilised with steam-air mixtures at 70°C. Both in pot experiments and in field trials, significantly higher yields were obtained on soil sterilised at 70°C than on soil sterilised at 100°C. In the pot experiments the average head weight of lettuce obtained from eight soil types was about 20% greater on the soil heated to 70°C than on the soil heated to 100°C. A similar increase in yield was found in the field trials conducted over two years. Apart from increased weight, lettuce grown on soil sterilised at 70°C was of significantly better quality with improved shape of head and showing less susceptibility to tipburn and marginal leaf scorch.

In the field experiments mentioned tomatoes followed the lettuce crops. The reaction of cucumbers to soil sterilisation at different temperatures was investigated in another field experiment. No significant differences in yield resulting from the treatments were found in tomatoes and cucumbers.

The manganese content of the crops grown on soil sterilised at 100°C was usually considerably higher than on soil sterilised at 70°C. This was the case particularly with lettuce which showed some very great differences on some soil types.

### INTRODUCTION

Steam sterilisation of the soil has undesirable side effects in some crops. Lettuce in particular may often show poor development if grown on newly steam-sterilised soil. Previous research has shown that this is usually the results of excessive manganese uptake by the crop<sup>7,9</sup>. The changes in the nitrogen status of the soil following steam sterilisation may also affect crop development<sup>7,10</sup>.

Investigations have shown that the degree to which the changes in the manganese and nitrogen status in the soil take place are closely connected with the temperature at which the soil is steril-

lised<sup>4 5 9 10</sup>. Bollen<sup>2</sup> has shown that all harmful fungi and bacteria are killed if the glasshouse soil is heated to 70°C. Mentioned results led to the supposition that it might be advisable to replace steam sterilisation of the soil at 100°C with sterilisation at 70°C. At the latter temperature level the chemical status of the soil would probably not be changed to the extent that it would affect the growth of lettuce. The effects of sterilisation at 70 and 100°C were therefore compared. Besides lettuce, tomatoes and cucumbers were used as test crops. In the meantime, some research workers have already obtained favourable results with soil sterilisation at temperatures below 100°C. Dawson *c.s.*, working with tomatoes<sup>4</sup>, obtained the best growth after treatment of the soil at temperatures of 65–70°C. In the case of cucumbers<sup>5</sup>, soil sterilisation at 100°C resulted in lower yields than treatment at 88°C. White<sup>11</sup> obtained better results with carnations at 60 and 71°C than at 100°C.

## METHODS

### *Soil sterilisation*

In two pot experiments the development of lettuce was compared on soil sterilised at 100 and 70°C. Untreated soil was also included in the experiments. The treatments were applied to different soil types. The soil was heated for about 12 hours. Sterilisation at 70°C was carried out with the aid of a steam-air mixture. Systems for the generation of steam-air mixtures have been described by Baker<sup>1</sup>, Brazelton<sup>3</sup> and Dawson *c.s.*<sup>5</sup>.

In field experiments lettuce as well as tomatoes and cucumbers were used. A comparison was made also in these experiments between soil heated to 70 and 100°C. Sterilisation at 70°C was carried out via an underground grid of tile drains and sterilisation at 100°C was carried out via the tile drains as well as with steaming sheets. The tile drains, the usual clay drain pipes with collars, had an internal diameter of 5 cm and were buried at a depth of 50 cm. The distance between the rows of drains was also 50 cm. For the temperatures obtained at different depths, see Nederpel<sup>8</sup>.

### *Crops and soils used*

The pot experiments were carried out in 1969 and 1970. The lettuce used in the experiments was planted out in 1969 in mid-October and in 1970 at the end of September. The varieties used were Deci-Minor and Deciso respectively. The harvest took place in December. Five different soil types were used in 1969 and three in 1970. Table 1 shows some analytical data of the different soil types which are important for the interpretation of the results. In 1969, a start was made on two field experiments in which lettuce and tomatoes were grown. The soil on the holdings on which the experiments were carried out

TABLE 1

Analytical data of the soils in the pot experiments

Number	Year	Soil type	Organic matter %	CaCO <sub>3</sub> %	pH	Active Mn, ppm
1	1969	Dune sand	4	0.2	6.8	16
2	1969	Loamy sand	3	0.5	7.2	24
3	1969	River loam	7	0.1	5.5	157
4	1969	Sea loam	10	2.3	7.3	147
5	1969	Peaty clay	23	0.0	4.9	42
6	1970	Sea loam	15	1.2	7.1	91
7	1970	Clayey peat	25	1.2	6.7	78
8	1970	Potting compost	43	0.8	5.5	12

TABLE 2

Analytical data of the soils in the field experiments

Holding	Soil type	Organic matter %	CaCO <sub>3</sub> %	pH	Active Mn, ppm
Pijnacker	Sea loam	12	4.9	7.0	99
Bleiswijk	Sea loam	9	6.0	7.4	80
Naaldwijk	Loamy sand	4	1.6	6.8	30

consisted of sea loam for which some characteristic analytical data are given in Table 2. The following cropping programme was used on both holdings:

Soil sterilisation	August – September 1969
Lettuce crop	October – December 1969
Tomato crop	January – August 1970
Soil sterilisation	August – September 1970
Lettuce crop	October – December 1970
Tomato crop	January – August 1971

The following treatments were compared in the experiments:

- Steaming with the aid of sheets
- Steaming via tile drains, and
- Treatment with a steam-air mixture at 70°C, also via tile drains.

Another experiment was started on loamy sand at Naaldwijk in 1970 (Table 2) which included, apart from the three treatments mentioned, another treatment, *viz* sterilisation of the soil with a steam-air mixture at 85°C. Cucumbers were used as the test crop in this experiment.

#### Soil testing

Soil tests were made in the pot as well as in the field experiments. In the

field experiments the sampling depth was 30 cm. The samples were dried at 45°C and tested for exchangeable and active manganese.

Exchangeable manganese was determined by extraction with Morgan's solution. This is a buffer solution of acetic acid and sodium acetate (pH 4.8). The extraction ratio used was one part soil and 2½ parts extractant.

Active manganese was determined with the aid of the same extractant to which hydroxylamine-hydrochloride was added as a reducing agent<sup>6</sup>. In both analyses the manganese contents were expressed in ppm of the extract.

## RESULTS

### *Pot experiments*

The weights of the lettuce in the pot experiments are given in Table 3. The figures show that the yields were considerably higher in 1970 than in 1969. This was caused mainly by the different plant-

TABLE 3  
Yield of lettuce in kg per 100 heads in the pot experiments.

Soil type	Year	Treatment		
		Control	70°C	100°C
1	1969	12.2	12.8	12.5
2	1969	12.0	12.7	12.4
3	1969	12.6	14.0	11.5
4	1969	12.4	13.1	10.4
5	1969	8.6	11.2	2.0
6	1970	19.2	21.2	19.3
7	1970	18.6	20.8	17.0
8	1970	17.3	17.7	18.8

ing dates. With the exception of no. 8 (potting compost) yields were highest on soils sterilised at 70°C. In several cases the weights of lettuce harvested from soil sterilised at 100°C were even lower than the yields from untreated soil. This shows that the unfavourable side effects of soil sterilisation on the growth of the crop outweighed the growth stimulance normally expected from soil sterilisation. The difference in head weight obtained from soil treated at 70 and 100°C was greatest on the soils which were rich in active manganese. The difference was particularly great on the peaty clay (no. 5). The very low yield obtained from this soil after sterilisation at 100°C was probably due to the presence of nitrite. Shortly after

planting out, the crop showed symptoms which were very similar to those described for nitrite toxicity<sup>10</sup>.

In Table 4, the contents of exchangeable manganese in the soil and the manganese content of the crop are given. The increase in the content of exchangeable manganese as a result of sterilisation at 70°C was considerable only on the peaty clay soil. On soils sterilised at 100°C the increase was usually very great with the exception of the potting compost (no. 8). The increase in exchangeable manganese was greatest on soils rich in active manganese.

TABLE 4

The content of exchangeable manganese in soil (in ppm of the Morgan's extract) and the manganese content of lettuce (in ppm of the dry matter) in the pot experiments.

Soil type	Year	Soil			Heads		
		Control	70°C	100°C	Control	70°C	100°C
1	1969	2	3	10	76	102	154
2	1969	9	8	20	37	74	215
3	1969	9	14	74	64	165	903
4	1969	16	18	46	43	85	264
5	1969	14	28	38	151	339	378
6	1970	9	9	54	69	104	336
7	1970	5	5	54	26	32	320
8	1970	5	3	4	59	120	125

On soil sterilised at 100°C, the manganese content of the crop was usually several times that of the crop on untreated soil. In case of sterilisation at 70°C the content was high only on the peaty clay soil. This soil had a low pH and showed a sharp increase in exchangeable manganese after heating at 70°C.

On the whole, the quality of the lettuce was very much poorer on the soil sterilised at 100°C than with the other treatments. This showed up for instance in the marginal leaf scorch assessment. The results of this are given in Table 5. No assessment figures are given for the peaty clay soil as the great difference in weight made a fair comparison impossible. It is clear that most of the marginal leaf scorch was found on soils treated at 100°C.

#### *Field experiments*

The results of lettuce and tomatoes are given in Table 6 and of

TABLE 5

Index figures for marginal leaf scorch in the pot experiments; 1-3 light, 4-6 moderate and 7-10 severe symptoms.

Soil type	Year	Treatment		
		Control	70°C	100°C
1	1969	2.2	4.5	4.8
2	1969	0.5	3.5	5.2
3	1969	1.2	1.0	4.2
4	1969	0.0	3.0	1.2
5	1969	—	—	—
6	1970	1.2	1.6	2.0
7	1970	1.0	1.4	2.5
8	1970	1.3	1.9	1.8

TABLE 6

Yield of lettuce (kg per 100 heads) and tomatoes (kg per plant) in the field experiments at Pijnacker and Bleiswijk.

Treatment	Pijnacker				Bleiswijk			
	Lettuce		Tomatoes		Lettuce		Tomatoes	
	1969	1970	1970	1971	1969	1970	1970	1971
Sheets 100°C	17.3	13.9	5.2	4.9	15.0	18.3	5.6	2.3
Tiles 100°C	17.5	14.4	5.2	4.7	16.1	19.8	5.4	2.2
Tiles 70°C	19.7	15.8	5.1	4.9	19.3	24.9	5.5	2.3

TABLE 7

Yield of cucumbers in the field experiment at Naaldwijk

Treatment	kg/plant
Tiles 70°C	27.8
Tiles 85°C	27.8
Tiles 100°C	29.0
Sheets 100°C	27.0

cucumbers in Table 7. The figures show that the weights of lettuce obtained from soil sterilised at 70°C were considerably higher than those from soil sterilised at 100°C. The lettuce from soil sterilised at 70°C also had improved shape of heads and was less susceptible to marginal leaf scorch and tipburn. The latter showed up in 1969

when on the holding at Bleiswijk more than 60 per cent of the lettuce on soil sterilised at 100°C had tipburn compared with about 30 per cent on soil sterilised at 70°C. Marginal leaf scorch was rather serious on the holding at Pijnacker in the same year. However, on the soil sterilised at 70°C the disorder was much less severe than on the soil sterilised at 100°C.

The differences in the yields of tomatoes and cucumbers with the various treatments were only small and not significant. The low yields obtained on the holding at Bleiswijk in 1971 were caused by early clearance of the crop.

TABLE 8

The content of exchangeable manganese in the soil (in ppm of the Morgan's extract) in the field experiments.

Holding	Year	Treatment			
		Tiles 70°C	Tiles 85°C	Tiles 100°C	Sheets 100°C
Pijnacker	1969	28	—	55	54
	1970	16	—	46	46
Bleiswijk	1969	18	—	49	52
	1970	22	—	48	52
Naaldwijk	1970	23	25	28	30

The results of the soil analyses of the field experiments are given in Table 8 and the results of the crop analyses are given in Table 9. As with the pot experiments, the contents of exchangeable manganese and the manganese contents of the crop were found to be highest on the soil sterilised at 100°C. No systematic differences were found between sheet steaming and steaming via the drainage grid.

#### *Discussion and conclusions*

In the Netherlands many glasshouse soils are steam sterilised in order to control soil organisms pathogenic to tomatoes and cucumbers. Steam sterilisation is usually carried out before the lettuce crop which normally precedes the tomato or cucumber crop. However, steaming often causes undesirable side effects in the lettuce crop during the initial period after the treatment. These effects are often the result of excessive uptake of manganese. Adequate measures of prevention have not yet been found and it may therefore be

TABLE 9

The manganese content of the crops (in ppm of the dry matter) in the field experiments. With lettuce whole heads were analysed and with tomatoes and cucumbers young fully grown leaves.

Holding	Crops	Year	Treatment			
			Tiles 70°C	Tiles 85°C	Tiles 100°C	Sheets 100°C
Pijnacker	Lettuce	1969	106		426	315
	Lettuce	1970	44		301	338
Bleiswijk	Lettuce	1969	75		280	326
	Lettuce	1970	52		358	268
Pijnacker	Tomatoes	1970	48		136	144
	Tomatoes	1971	40		126	225
Bleiswijk	Tomatoes	1970	148		188	166
	Tomatoes	1971	43		174	158
Naaldwijk	Cucumbers	1971	131	476	757	525

advisable to carry out the steaming operation after the lettuce crop and before the tomato or cucumber crop. The control of pathogenic soil organisms is particularly important for these crops besides which tomatoes and cucumbers are much less susceptible to excessive manganese uptake. However, many growers will continue to steam the soil before the lettuce crop because of the tight cropping programme and the less suitable condition of the soil after the lettuce crop (low temperature and high moisture content).

This investigation has shown that no undesirable side effects need occur in lettuce if the soil is sterilised at 70°C instead of being sterilised at 100°C. The quantity of manganese released in the soil at 70°C is only small. The manganese content of the crop is only slightly increased and the danger level for lettuce is seldom reached. This may occur on soils with a low pH, but manganese toxicity is also possible in that case on unsterilised soil.

Sterilisation of the soil at 70°C will only be acceptable if it is shown in practice that the control of pathogenic soil organisms is adequate at this temperature. The results of the field experiments described and those obtained by other research workers give good grounds for the hope that this may be the case. However, further research is required.

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