SOIL DISINFECTION WITH FUMIGANTS IN GLASSHOUSE TOMATOES

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SUMMARY

In the Netherlands the three main soil-borne diseases of glasshouse tomatoes are:
Corky-root (probably caused by a virus)
Root-knot nematode (*Meloidogyne* sp.)
Wilt-disease (*Verticillium*)
Before the second World War these diseases were controlled by steam sterilization or by carbon-disulfide and formaldehyde. After the war the fumigants DD (dichloropropane + dichloropropene), ethylene-dibromide, and chloropicrin were introduced. The former two are specific nematocides and can only be used for the control of the root-knot nematode. Chloropicrin gives control of all three soil-borne diseases, especially on light soils. Nowadays nearly every grower uses one of the chemicals once in 2–3 years. The fumigants are put into the soil by a motor injector or, if necessary, with a hand injector. The chemicals are applied in the months of August to December. The results are better in August and September than in October and November, as the soil temperature is higher in the first two months.
Besides the anti-parasitical action the fumigants possess a growth stimulating effect. This is especially the case with chloropicrin. The cause of this phenomenon cannot yet be explained entirely, though there are some indications as to the solution of this problem. For instance, after application of chloropicrin the bacterial population in treated soil proved to be much higher than in non-treated soil. Furthermore, the level of the N-mineralization appeared to be higher in treated soil than in non-treated soil. These two processes are probably closely connected with each other.

The aim of this paper is to give a general view of the use of fumigants in tomato growing in Holland and to show some results of experiments carried out at our Experiment Station.

SOIL-BORNE DISEASES

In the Netherlands tomatoes have been grown under glass for about 50 years, and as crop rotation is impossible in glasshouse culture, the tomatoes are attacked by several soil-borne diseases. The most important of these are:

A) *Corky-root*, which is probably caused by a virus (fig. 1). In nearly every glasshouse in Holland corky-root may be found, and every year it is a cause of considerable losses in the crops.

B) *Root-knot nematode* (*Meloidogyne* sp., formerly *Heterodera marioni*) (fig. 2). Nowadays this nematode causes but little damage, as very effective chemicals can be applied.

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FIG. 1

FIG. 2

C) *Wilt-disease* (*Verticillium albo-atrum* and *V. dahliae*), which occurs frequently, but in many cases it can be effectively controlled by cultural measures.

D) *Potato-eelworm* (*Heterodera rostochiensis*). In Holland this eelworm occurs only sporadically and it is practically no problem.

Roughly estimated, the first three diseases reduce the yield by about 10 %. This means that in 1954, when the total yield of tomatoes in Holland was about 110 mill. kg, more than 10 mill. kg were lost due to soil-borne diseases. For the individual grower the loss may even be higher; a yield reduction of 30–40 % is no exception.

Before the second World War, formaldehyde and carbondisulfide were used for soil sterilization (steam sterilization was and is still used on a large scale, but this is not dealt with in this paper). The results with these chemicals fluctuated and were unsatisfactory in comparison with the present-day fumigants.

FUMIGATION AS A CONTROL

After the second World War the application of fumigants for soil disinfection has increased enormously. It has completely changed the nature of soil disinfection in Dutch tomato-growing.

The control of the root-knot nematode is no longer a problem. Several fumigants can be used successfully. In sequence of decreasing activity they are:

DD (a mixture of 1.2-dichloropropane + 1.3-dichloropropene),
E.D.B. (ethylene dibromide),
Chloropicrin (trichloronitromethane),
Methylbromide.

Chlorobromopropene can also be used against this nematode. Up to this moment, however, little practical experience has been obtained with this chemical. The results with methylbromide can be highly improved by covering the soil with sheets of plastic or paper after the treatment. In practice, however, this method meets with several difficulties.

The potato-eelworm can be effectively controlled with DD, though it is necessary to use double the dosage needed for the control of the root-knot nematode. Chloropicrin also gives good results against the potato-eelworm. The results with ethylene dibromide and methylbromide, on the other hand, are poor.

Application of fumigants is usually not necessary for the control of *Verticillium*. As already said, this disease can be controlled rather easily by cultural measures. If necessary, formaldehyde or chloropicrin may be used.

Among the soil-borne diseases here mentioned corky-root is the most difficult to control. Chloropicrin is the only chemical that controls this disease. This is to a certain degree also the case with formaldehyde, but only on sandy soils.

None of the above-mentioned soil-borne diseases can, however, be entirely eradicated by fumigants. Hence it is necessary to repeat the treatments regularly. In practice nearly every grower has his soil disinfected every 2–3 years, while several growers sterilize their soil annually.

The application of fumigants is always done by contractors in Holland. Apparatuses designed for this special job, the so-called motor injectors, are used (fig. 3). On places where a motor injector cannot be used, the fumigant is put into the soil by a hand injector.

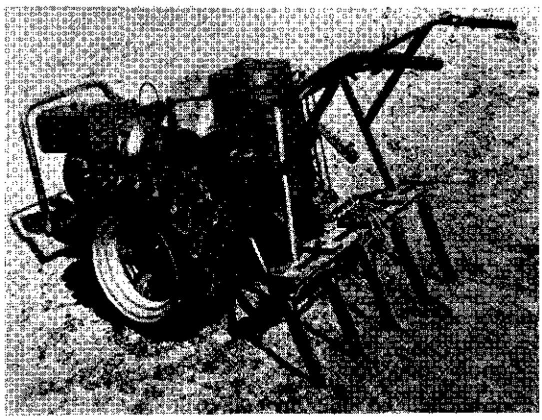

FIG. 3

FACTORS IN FUMIGANT ACTION

The action of these fumigants depends on several factors.

(1) *Temperature.* The higher the temperature, the better the results of soil-disinfection. One should, however, avoid too high a soil temperature. In this case the chemical would evaporate too quickly and hence remain too short in the soil to kill the parasite sufficiently. This may be redressed by covering the soil with plastic or paper. But as already said, in practice this is rather unfeasible. The best soil temperature without using covering materials is 15°–20°C. Even then one must use a water seal after treatment with fumigants such as E.D.B. and chloropicrin. If the soil temperature is lower than 10°C., the fumigants are usually less effective. This was clearly demonstrated by an inquiry among hundreds of growers. It was found that in case of application after the first of October the results of soil-disinfection were less effective in about 20 % of the cases, whereas this percentage was only 6 if the fumigants were applied before this date.

(2) *Soil-type.* The best results with chemical soil-disinfection are gained on very light soils. When the soil contains more clay or peat the chemicals are less effective and a higher dosage is needed to give adequate control. This is especially the case for the control of corky-root with chloropicrin. In table I the influence of the soil-type on the results of chloropicrin against corky-root is shown.

TABLE I. Influence of the soil type on the results of chloropicrin against corky-root (0 = no infestation; 10 = very heavy infestation)

Soil-type	Dosage			
	3.5 l/100 m²	4.2 l/100 m²	5.0 l/100 m²	Untreated
Sand	1.8	1.5	1.0	8.5
Loam	4.5	3.0		9.5
Clay		6.7	4.7	8.6
Peat		3.6	3.0	8.7

(3) *Soil-structure.* On soils with a bad structure it is difficult to get a sufficient control of the parasites even if higher dosages are used. The fumigants cannot sufficiently penetrate everywhere. In these circumstances improvement of the soil-structure is the only possible way to get better results.

(4) *Soil-moisture.* During the application the soil must not be too wet or too dry. The soil-moisture of a seedbed is best.

Besides insecticidal, nematocidal and fungicidal action these chemicals also possess herbicidal action. This was clearly demonstrated in several experiments. In table II the results of one of these experiments are given.

TABLE II. Herbicidal action of DD and chloropicrin

	Total numbers of plants two months after treatment		
	DD	Chloropicrin	Untreated
Monocotyles	4	7	84
Dicotyles	6	5	186

GROWTH STIMULATION BY FUMIGANTS

Not only do these fumigants kill parasites, but they also have a growth-stimulating effect on plants. Consequently, the application of such a substance stimulates the growth of the plant resulting in a higher yield, even when no soil-borne parasites are present. Many tomato-growers in Holland even use fumigants merely for the latter effect. This phenomenon is most clearly demonstrated with chloropicrin.

Although the cause of this growth-stimulating effect is not yet entirely clear, there are some factors that indicate an explanation. In a number of experiments carried out at our Experiment Station the bacterial activity of the soil was found to be greatly stimulated by an application of chloropicrin. During a long time the bacterial population is on a higher level than in the untreated plots. The stimulation of bacterial activity will certainly improve the soil fertility, and therefore result in a better growth of the plant.

In addition to these studies on the bacterial population, experiments were carried out to investigate the N-mineralization. (The N-mineralization is a criterion for the mobilization of nitrogen from organic material). It appeared that after soil treatment with chloropicrin, the N-mineralization is for a long time higher than in the untreated plots. This gradual and regular mobilization of nitrogen is of great importance for the growth of the plants. In table III the ratio of bacterial population of plots treated with chloropicrin and untreated plots and the ratio of N-mineralization of these two are shown.

TABLE III. Comparison of bacterial populations and N-mineralization of plots treated with chloropicrin and untreated plots

	Days after treatment	Bact. pop. chlpr./Bact. pop. untr.	N. min. chlpr./N. min. untr.
Experiment I	19	10	3½
	35	2	1½
	48	2	2
	62	4	2
	76	2	1½
Experiment II	22	2½	1¼
	36	3½	1¼
	50	10	1¼
	78	1½	1¼
	106	1	1
Experiment III	75	2	1⅛
	102	1½	1¼
	116	2	1¼
	130	3	1⅛

Though it is not so evident, the phenomenon of a higher bacterial population and a higher N-mineralisation is also observed when the other fumigants are applied.

DISCUSSION

Reduction of root-knot nematode by fumigation

After treatment with DD the root-knot nematode population is reduced by 95–99% and after treatment with chloropicrin by about 80% (J. H. SCHUURMANS STEKHOVEN, Netherlands).

Precautions when using fumigants

When using chloropicrin it is always necessary to wear a gasmask; with the other chemicals only in case of warm weather (I. M. BURNET, U.K.).

Experience with chlorobromopropene

CBP gives very good results against the rootknot nematode. The results against corky-root are still somewhat doubtful (E. STRØMME, Norway).

Reduction of the cyst population of potato root eelworm by DD
A high dosage of DD indeed reduces the population of the potato root eelworm to useful economic levels. It is, however, necessary to repeat the treatment regularly (J. S. PANTON, U.K.).

Control of Verticillium wilt by chloropicrin
On soils with a good structure chloropicrin gives good results against Verticillium. On soils with a bad structure, on the other hand, the results are poor (F. G. SMITH, U.K.).

Corky-root, a virus
PROF. THUNG at Wageningen, who is doing research into the origin of corky-root, found that it is caused by a tobacco necrosis virus (E. R. HOARE, U.K.).

Reduction of crop by corky-root
Contrary to the experience in England, the crop reduction in Holland by corky-root may be very high, especially on light soils. Crop reductions of 30 to 40% are no exception (E. R. HOARE, U.K.).