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The influence of soil temperature and moisture content on the effect of soil fumigants[1]

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Abstract

Laboratory experiments were carried out to test the effect of two levels of soil moisture and two temperatures on the effectivity and persistence of five soil fumigants.

Soil moisture had a great influence on the extent of the zone over which the products diffused vertically, as shown by fungicidal and phytotoxic action at various depths in soil columns. In moist soil spread of the gases from the point of application is much poorer than in dry soils. There was little or no temperature effect in the dryer soil, while in the wet soil diffusion was better at 25° than at 10 °C.

In studying persistence, as measured by assaying inhibition of germination and growth of *Lepidium sativum*, it appeared that the tested fumigants can be divided into two groups. In the case of chloropicrin and telone persistence is primarily enhanced by high soil moisture content, and in the case of the fumigants having methyl isothiocyanate as the active principle, by a low soil temperature. With chloropicrin and telone, there is a temperature effect only in the moist soil. Persistence of methylisothiocyanate is only slightly affected by soil moisture.

Introduction

The purpose of our studies is to define the conditions through which soil fumigants reach a maximal fungicidal activity combined with a short phytotoxical persistence in the treated soil. Domsch (1964) investigated the fungicidal activity of several fungicides and, among others, also of some soil disinfectants. The research of Kreutzer (1960) and of Goring (1962) is focused on the general biocidal effect of these products as well as on the factors acting upon this effect. The last mentioned author also investigated thoroughly the adsorption of soil fumigants by the soil. The research of Van Assche et al. (1967, 1968 and 1969) and Van den Broeck (1968) was directed towards a more exhaustive study of the factors affecting soil disinfection. In the present study the influence of soil temperature and moisture on the action of five soil fumigants was investigated.

Materials and methods

The method used has already been described in detail by Van Assche et al. (1967). After treating a 40 cm soil column with the different fumigants, test material was inserted at 4 different levels, i.e. every other 10 cm varying from 0 to 30 cm depth. The test material was renewed periodically. The fungi *Rhizoctonia solani*, *Sclerotinia minor*

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and *Fusarium oxysporum* were used to test the fungicidal effect and *Lepidium sativum* for the phytotoxic and phytocidal effect of the products. The results, as represented in the figures, are based upon the effect (lethal or not) on the fungi for the evaluation of the fungicidal action, and on the germination of the seeds and the growth of the seedlings, for measuring phytotoxicity. The grading of the seedlings was made as discribed by Van Assche et al (1967). The phytotoxic value 10 is used when there is no germination at all, and the value 0 in case of a normal growth of the seedlings. The sum of the values taken at four different depths gives the phytotoxic value, of which the maximum is 40. By inserting new test materials at regular intervals, there is a possibility in change of the phytotoxic values (Fig. 3–7).

The fungicidal effect was stated only once (at the start of the experiment) in the same way. Here also the maximum value is 40. Of course it goes without saying that it is impossible to connect these values with a centimeter scale. They are only able to give us an idea of the phytotoxic and fungicidal effect of the fumigants used.

Metam-Na (380 g/l sodium-N- methyldithiocarbamate, A. I.: methylisothiocyanate (MIT)), telone (1093.5 g/l 1,3-dichloropropene), and ditrapex (20% MIT and 80% 1,2-dichloropropane – 1,3 dichloropropene) were applied at a dosage of 100 ml/m^2. Chloropicrin (1600 g/l trichloronitromethane) was used at 50 ml/m^2. These four products were injected in the soil at a depth of 15 cm. Dazomet (85% 3,5-dimethyl-tetrahydrc-1, 3, 5 (2H)-thiadiazine-2-thione, A.I.: MIT) was mixed thoroughly in the upper 10 cm of the soil at a dosage of 50 g/m^2.

The experiments were carried out in a sandy-loam soil with a pH of 7.3 and an organic matter content of 5%. The two levels of moisture content of the soil were 45% and 70% of saturation (RMC). Per volume unit, the amount of air-dried soil was the same in both cases. The apparent density of the soil, Ds (weight/volume ratio), was 1.5 for the moist soil and 1.2 for the dryer soil. After treatment the soil was kept at constant temperatures, viz 10 °C and 25 °C. To reduce desiccation to a minimum the relative air humidity was kept at 95%.

Results and discussion

Fungicidal effect

The fungicidal effect of the 5 products after a seven-day contact at two temperatures is shown in Fig. 1 and 2. The fungicidal value is much higher at 45% than at 70% relative moisture content, and is affected to a lesser degree by the temperature, the fungicidal value being somewhat higher, in some cases, at 25 °C than at 10 °C.

With chloropicrin, the fungi are killed at all points sampled for both temperatures at 45% relative moisture content. At 70% moisture content there is a temperature effect: at 10 °C the fungicidal zone is situated between 10 and 30, at 25 °C between 0 and 20. As the vapour-pressure of chloropicrin is much lower at 10 °C than at 25°C, it can be supposed that at 10 °C a higher concentration of chloropicrin gas is maintained for some time, thus allowing the gas, which is heavier than air, to penetrate deeper than at 25 °C. On the other hand, diffusion through the superficial layers will be slow as a result of the low vapour pressure and the low porosity, and thus the lethal concentration is not reached at the surface at 10 °C.

In the case of metam-Na the extent of the fungicidal values is also practically the same for both temperatures at 45% relative moisture content. At 70% moisture con-

Fig. 1. Fungicidal activity at 10 °C of soil fumigants in a sandy loam soil at different moisture contents.
R. *Rhizoctonia solani;* F. *Fusarium oxysporum;* S. *Sclerotinia minor.*
a. 45 % RMC; b. 70 % RMC.

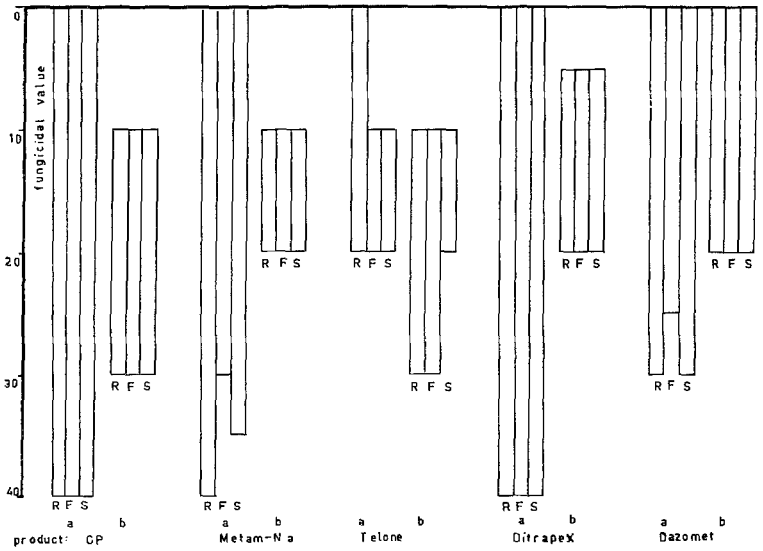


Fig. 1. Fungicide activiteit van grondontsmettingsmiddelen bij 10 °C in een zandleemgrond bij verschillende vochtigheidsgraad.

Fig. 2. Fungicidal activity at 25 °C of soil fumigants in a sandy loam soil at different moisture contents.
R. Rhizoctonia solani; F. Fusarium oxysporum; S. Sclerotinia minor.
a. 45 % RMC; b. 70 % RMC.

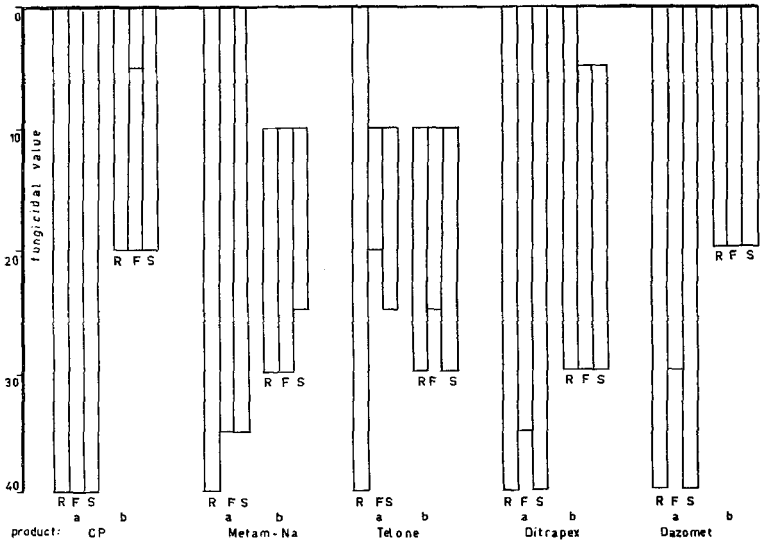


Fig. 2. Fungicide activiteit van grondontsmettingsmiddelen bij 25 °C in een zandleemgrond bij verschillende vochtigheidsgraad.

tent, the values are much smaller and are affected by temperature. It seems probable that the limited extent of the fungicidal value at 10 °C is based on both slow hydrolysis of Metam-Na to the active compound MIT, and on slow diffusion of the MIT-gas.

Telone is primarily a nematicide, but our results enable us once more to draw attention to its fungicidal properties, which are apparent in Fig. 1 and 2, especially with regard to *Rhizoctonia solani*, which is the most susceptible. When conditions for a fast diffusion exist (25 °C, 45 % moisture content), lethal concentration for this fungus is reached over the whole soil column. At 70 % moisture content the fungicidal values are similar to the ones found with chloropicrin and metam-Na; this can be explained by the poor diffusion under these conditions which leads to a high (fungicidal) gas concentration over a limited distance from the injection point.

Ditrapex is a mixture, and the fact that the fungicidal values are generally much larger than the ones seen with telone illustrates the strong fungicidal effect of MIT, which comprises only 20 % of the mixture. Again there is little or no influence of the temperature at 45 % relative moisture content. At 70 % relative moisture content, the fungicidal values are larger at 25 ° than at 10 °C because of the faster diffusion. Also the values are larger than the ones observed with metam-Na in the same conditions, which again suggests that in the case of metam-Na, not only the diffusion of the MIT gas, but also the breakdown of the original compound to the active MIT is a necessary step to fungicidal action.

Dazomet is a powder, and it has been mixed with the upper 10 cm of the soil. This explains the good fungicidal action at the surface in all cases. There is a temperature effect in this case at 45 % relative moisture content, but not at 70 % moisture content. The latter observation may be partly related to the faster hydrolysis to the active MIT at the higher moisture level.

Fig. 3. Phytotoxic value of chloropicrin at different temperatures and moisture contents.
1. 45 % RMC, 10 °C; 2. 70 % RMC, 10 °C; 3. 45 % RMC, 25 °C; 4. 70 % RMC, 25 °C.

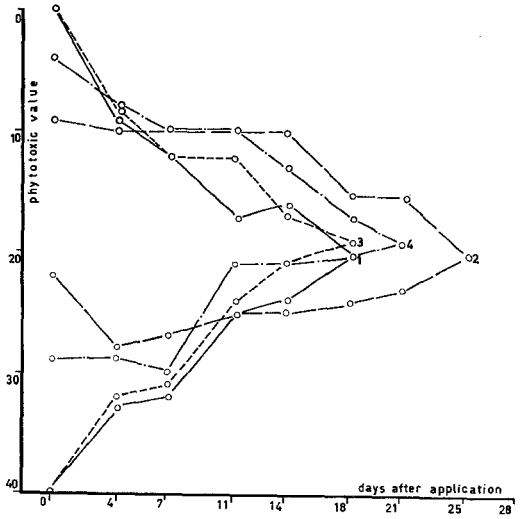


Fig. 3. Fytotoxische waarde van chloorpicrine bij verschillende temperatuur en vochtigheidsgraad.

Phytotoxic effect

Selecting the best treatment, especially for glasshouse crops and horticulture, not only depends on the fungicidal action as discussed above, but also on the phytotoxical and phytocidal persistence. In fact for these cultures with high economical value the need of only a short waiting time is very important.

In the case of chloropicrin (Fig. 3) the development of the phytotoxic value with time, and with the various treatments, shows primarily an effect of the porosity (moisture content). At 45% moisture content spreading of the gas in the soil is better, and the persistence is shorter, than at 70% moisture content, and there is no difference between the results observed at both temperatures when soil moisture content is 45%. At 70% moisture content the best initial spread in the soil columns and the shortest persistence were observed at the highest temperature, 25 °C.

Contrary to what has been shown for chloropicrin, the persistence of metam-Na (Fig. 4) is largely influenced by the temperature. At 10°C the persistence lasts up to 6 weeks, as compared to less than 2 weeks at 25 °C. This long persistence at the lowest temperature can be explained by the slow transformation of metam-Na to the active compound MIT, the low vapour pressure of MIT, and for the dryer soil, by the strong adsorption of the apolar MIT. The horizontal character of Line 2 may be partly explained by adsorption of the polar metam-Na at the moist soil-elements. The initial extent of the phytotoxic value is largely affected by the moisture content and corresponds quite closely to what has been shown for the fungicidal effect of metam-Na (Fig. 1 and 2).

The results of the treatment with telone are shown in Fig. 5. A comparison with Fig. 1 and 2 shows that the initial phytotoxic value is generally larger than the fungicidal value, which illustrates the poor fungicidal activity of this product, which is primarily used as a nematicide. The phytotoxic activity of telone resembles that of chloropicrin

Fig. 4. Phytotoxic value of metam-Na at different temperatures and moisture contents.
1. 45% RMC, 10 °C; 2. 70% RMC, 10 °C; 3. 45% RMC, 25 °C; 4. 70% RMC, 25 °C.

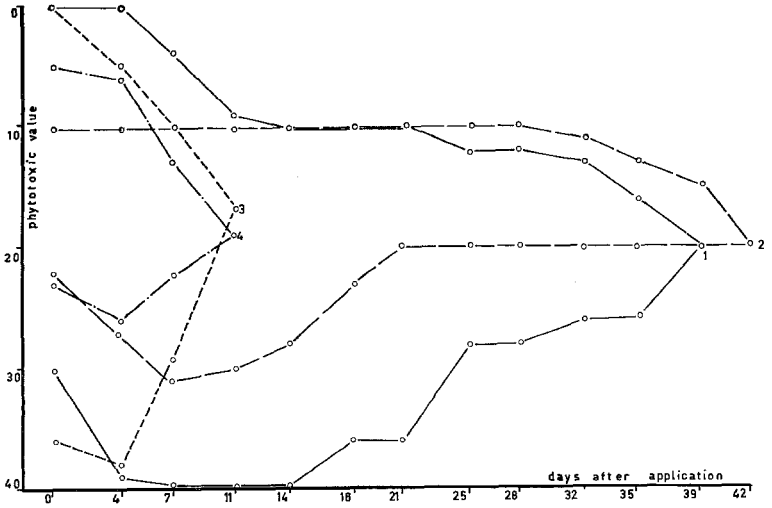


Fig. 4. Fytotoxische waarde van metam-Na bij verschillende temperatuur en vochtigheidsgraad.

Fig. 5. Phytotoxic value of telone at different temperatures and moisture contents.
1. 45% RMC, 10 °C; 2. 70% RMC, 10 °C; 3. 45% RMC, 25 °C; 4. 70% RMC, 25 °C.

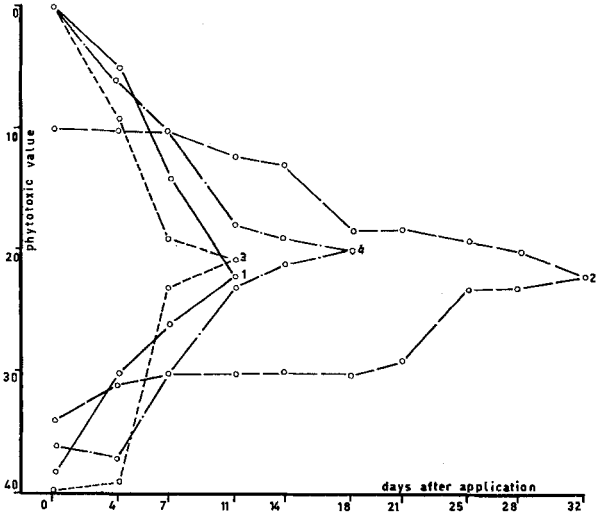


Fig. 5. Fytotoxische waarde van telone bij verschillende temperatuur en vochtigheidsgraad.

Fig. 6. Phytotoxic value of ditrapex at different temperatures and moisture contents.
1. 45% RMC, 10 °C; 2. 70% RMC, 10 °C; 3. 45% RMC, 25 °C; 4. 70% RMC 25 °C.

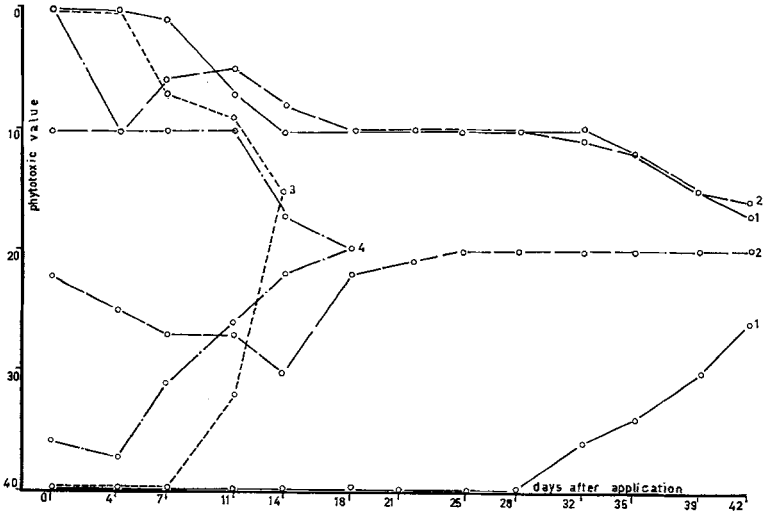


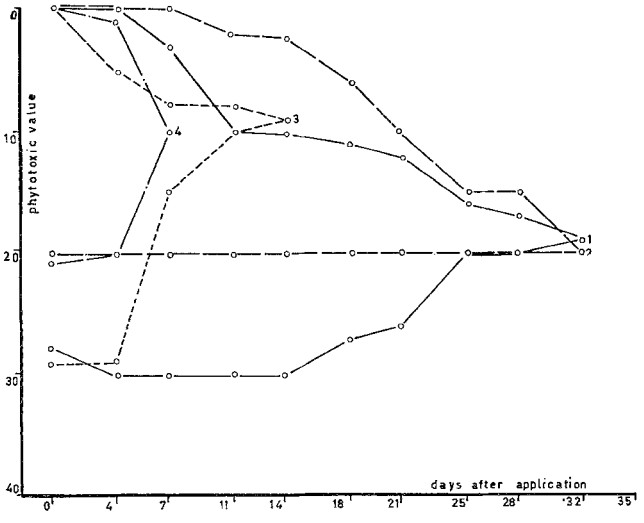
Fig. 6. Fytotoxische waarde van telone bij verschillende temperatuur en vochtigheidsgraad.

(Fig. 3). There is little temperature effect at 45 % moisture content; in the case of chloropicrin the initial phytotoxic value was smaller at 10 °C than at 25°C. Duration of the phytotoxic activity at 45 % moisture content is shorter with telone than with chloropicrin (11 and 18 days respectively). At 70 % moisture content it can be seen that the effect of the higher moisture content on the persistence is stronger with telone than with chloropicrin, and there also is a greater effect of the temperature on the phytotoxic persistence at 70 % moisture content. The initial phytotoxic value at 70 % moisture content is smaller at 10°C than at 25°C. The results altogether indicate that the effects of both soil porosity and soil temperature are more important in the case of telone than in the case of chloropicrin.

Ditrapex is composed of dichloropropene-dichloropropane mixture and MIT, and can therefore be expected to show phytotoxic effects related to the ones observed with telone and Metam-Na. Ditrapex (Fig. 6) shows indeed initial phytotoxic values which resemble those of telone (cf. Fig. 5), but in other respects the results resemble much more those of metam-Na (cf. Fig. 4). It is particularly clear that the persistence is mainly affected by the temperature, as is the case with metam-Na. Phytotoxicity of ditrapex even persists longer than metam-Na. At the lower temperature, high porosity has a favorable effect on penetration.

As can be expected, phytotoxic effects of dazomet (Fig. 7) are similar to those of metam-Na. Initial extent of phytotoxic values is largely affected by soil porosity, and the persistence by the temperature. Penetration is less and persistence generally shorter in the case of dazomet, as a result of the mode of application (mixing into the first 10 cm of the soil versus injection at 15 cm). This shows that in practice dazomet should be worked into the soil rather deeply. A plastic cover could further improve its performance, as is the case with the other fumigants.

Fig. 7. Phytotoxic value of dazomet at different temperatures and moisture contents.



1. 45 % RMC, 10 °C; 2. 70 % RMC, 10 °C; 3. 45 % RMC, 25 °C; 4. 70 % RMC, 25 °C.
Fig. 7. Fytotoxische waarde van dazomet bij verschillende temperatuur en vochtigheidsgraad.

Conclusions

A chemical soil disinfection is only interesting for intensive horticulture, if a good diffusion is combined with a phytotoxic and phytocidal effect of short duration. The circumstances determining these characters should be taken into account in the choice of the fumigant to be used. And on the other hand one should try to create conditions favorable for soil fumigation.

Generally we have found that a soil with a too low percentage of free pores, caused in this work by a high moisture content (70% relative moisture content), is detrimental to the diffusion of the active compounds. High soil temperature improves diffusion in moist soils, especially with ditrapex and telone.

With regard to the persistence, the tested fumigants can be divided into two groups. Persistence of chloropicrin and telone was primarily affected by porosity, and was shorter in the dryer soil (45% relative moisture content), with no effect of temperature. Persistence was longer in the moist soil, and there was an effect of the temperature, in that persistence was shortest with the highest temperature.

Persistence of metam-Na, ditrapex, and dazomet was mainly and markedly affected by temperature. With the lower temperature, the persistence was considerable (up to more than six weeks) as compared to what was observed at 25 °C (generally not exceeding two weeks). Effect of moisture content on persistence was small.

As was also suggested by some of our other experiments, under conditions which permit sufficient diffusion at a moderately high moisture level, a rather high moisture level in principle is not a drawback in the application of these three products, in connection with the low adsorption of the apolar MIT in moist soil, which leads to a short persistence.

Samenvatting

De invloed van bodemtemperatuur en vochtgehalte op het effect van grondontsmettingsmiddelen

In laboratoriumproeven werd de invloed van temperatuur en vochtgehalte van de bodem op de effectiviteit en persistentie van vijf grondontsmettingsmiddelen onderzocht.

De bodemvochtigheid heeft een grote invloed op de verspreiding der produkten, zoals bleek bij de toetsing van fungicide en phytotoxische effecten op verschillende diepten in grondkolommen. In vochtige grond met een laag poriënvolume is de verspreiding vanaf het injectiepunt bij deze gasvormige middelen veel geringer dan in droge grond. In vochtige grond was de ontsmette zone groter bij 25 °C dan bij 10 °C, terwijl in droge grond geen of weinig effect van de temperatuur werd geconstateerd.

Bij de bepaling van de persistentie, gemeten als kiem- en groeiremmend effect op *Lepidium sativum*, bleek de getoetste serie middelen in twee groepen uiteen te vallen. De persistentie wordt in het geval van chloorpicrine en telone vooral verlengd door een hoog vochtgehalte, en bij de drie andere, waarvan methylisothiocyanaat het actieve bestanddeel of principe is, door een lage temperatuur. Bij chloorpicrine en telone is er alleen een temperatuureffect in de vochtige grond, terwijl de persistentie van methylisothiocyanaat zeer weinig beïnvloed wordt door het vochtgehalte.

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