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Soil sterilization and glasshouse disinfection to control Fusarium oxysporum f. lycopersici in tomatoes in the Netherlands

G. WESTSTEIJN

Institute of Phytopathological Research (IPO), Wageningen*

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Abstract

Fusarium oxysporum Schlecht. f. *lycopersici* (Sacc.) Snyder & Hansen, was observed on tomatoes under glass in the Netherlands for the first time in 1968 and spread widely in the following years. Experiments showed that soil infestation could be reduced by sterilization with steam, methyl bromide and chloropicrin, provided the treatments were applied with great care. Disinfection of the glasshouse structures with formaldehyde killed deposited dry macroconidia but gaseous methyl bromide and chloropicrin and sprays of systemic fungicides, which are usually effective against *Fusarium* spp., did not.

Introduction

In 1968 a *Fusarium* sp. was isolated from wilting tomato plants under glass in the Netherlands and identified by the Centraalbureau voor Schimmelcultures at Baarn as *Fusarium oxysporum* Schlecht. f. *lycopersici* (Sacc.) Snyder & Hansen. Though this disease may have been present sporadically for some years, it was reported first on a few holdings, where relatively high day and night temperatures were maintained for early production. Later on it was found on many other holdings.

Symptoms as described for instance by Chupp (1925), Bewly (1928), Wollenweber and Reinking (1935), usually appeared from 5–6 weeks after planting, but in a few instances they were already observed during propagation. They have been described for conditions in the Netherlands by Weststeijn (1970). Symptom expression was most rapid and conspicuous in vigorously growing succulent plants as found by Clayton (1923).

To control this disease one can attempt: (a) to eradicate all inoculum on the holding, or (b) to protect the plants in an infested environment.

The eradication concerns all inoculum in or on the (1) glasshouse soil, (2) heating pipes and structural parts of the glasshouses, (3) sowing boxes, pots etc., (4) seed, (5) sowing and potting soil, (6) strings used as plant support, (7) equipment used for tending and harvesting the crop, (8) paths on the holding, (9) heaps of debris. This paper describes experiments on the disinfection of the items (1) and (2).

* Stationed at Glasshouse Crops Research and Experiment Station Naaldwijk, the Netherlands; present address: Bulb Research Centre, Lisse.

Materials and Methods

A soil sterilization experiment was laid out in 4 replicates on a heavily infested sandy soil. In mid-June the following treatments were applied: sheet steaming with nets for 12 hours, using an average of 10 l of fuel per m^2 and reaching 80 °C at a depth of 60 cm, chloropicrin at a dose of 60 ml/m^2 and methyl bromide at a dose of 100 g/m^2. After fumigation plastic covers were used as in normal practice. On July 10th each plot measuring 24 m^2, was planted with 22 plants and 38 guards of cv. 'Extase'. Numbers of diseased plants were counted at weekly intervals.

Conidia deposited on above ground parts of the glasshouses may be a source of reinfestation of the soil after soil sterilization. The number of macroconidia deposited on the heating pipes from plants on which the fungus sporulated profusely, was estimated by rinsing the pipes with water, collecting the conidia from this water by centrifuging, and counting with a haemocytometer.

Soil samples were taken on commercial holdings under heating pipes which had been disinfected with 4% formaldehyde and under those which had not. Besides, the soil elsewhere in the glasshouses was sampled, where no spores could have been washed into the soil. In all cases the glasshouse soil had been steam sterilized before disinfection of the pipes and the usual artificial rain had been applied before sampling. The soil samples were incubated in Wisconsin tanks at 25 °C and planted with 12 susceptible tomato plants per sample. Percentages of plants infected per sample were taken as a measure of soil infestation.

To study the effect of fungicides, dry macroconidia obtained from tomato stems were moistened by atomizing fungicidal suspensions. After drying the conidia were plated out on water agar to determine the percentage of germination.

To investigate the effect of gaseous methyl bromide and chloropicrin in the atmosphere of the glasshouse during fumigation on germination of macroconidia, dry conidia were exposed above the plastic soil cover during some routine treatments on private holdings. During methyl bromide fumigation macroconidia were also exposed under the plastic cover. Likewise the effect of formaldehyde was examined by spraying a glasshouse, in which samples of conidia had been distributed in such a way, that some were moistened and others exposed to the formaldehyde gas only. Immediately afterwards, the percentage of spore germination was determined as described above; a second count was made a few weeks later to exclude temporary effects.

Results

Soil sterilization. The results are summarized in Table 1. All treatments were significantly better than the control ($P<0.01$), whereas there was no significant difference between steam, chloropicrin and methyl bromide.

Disinfection of heating pipes. By rinsing the heating pipes 30,000 macroconidia per running metre of pipe were collected. This shows the importance of this potential source of reinfestation of the soil and underlines the need for disinfection. The mean percentages of diseased plants in soil sampled from under pipes disinfected with 4% formaldehyde, from below non disinfected ones and from other places in the glasshouses where no spores could have been washed into the soil, were 30%, 58%, and

Table 1. The influence of soil sterilization on the mean number of experimental plants per plot infected by *F. oxysporum* f. *lycopersici* (4 replicates of 22 plants each).

Treatment	Observation date				
	19/8	26/8	2/9	9/9	16/9
sheet steaming	0	0.5	0.5	0.5	0.8
methyl bromide 100 g/m²	0.5	1.0	2.0	2.0	2.3
chloropicrin 60 ml/m²	0	0.5	0.5	1.0	1.3
no sterilization	13.8	17.5	20.3	20.8	21.0

Tabel 1. De invloed van grondontsmetting op het gemiddelde aantal door F. oxysporum f. lycopersici aangetaste proefplanten per veldje (4 herhalingen van elk 22 planten).

Table 2. The effect of fungicidal sprays on the germination of macroconidia of *F. oxysporum* f. *lycopersici* (in %, based on approximately 300 macroconidia per treatment).

Active ingredient	Concentration (%)	Germination (%)
formaldehyde	4	0
thiophanate-methyl	0.1	72.4
benomyl	0.1	57.8
thiabendazole	0.1	59.5
iodine	0.5	77.5
water control		71.3

Tabel 2. De invloed van fungicide bespuiting op de kieming van macroconidiën van F. oxysporum f. lycopersici (in %, gebaseerd op ongeveer 300 macroconidiën per behandeling).

31 %, respectively.

The figures of Table 2 indicate that the systemic fungicides of the benzimidazole group as well as a general disinfectant based on iodine were ineffective in preventing germination of macroconidia and therefore could not replace formaldehyde for disinfection of the heating pipes.

During fumigation under commercial conditions, the germination of conidia exposed to the methyl bromide and chloropicrin concentrations above the plastic cover was reduced to only 60 % and 81 %, respectively; those exposed to the methyl bromide concentrations under the plastic cover for the same length of time did not germinate any more. The concentrations of methyl bromide above the plastic cover varied from 25–70 ppm, but that under the plastic sometimes exceeded 2,000 ppm. The conidia treated with liquid formaldehyde did not germinate, but 68 % of those treated with the gas did.

Discussion

Soil sterilzation by steam, chloropicrin and methyl bromide decreased the infestation of *Fusarium oxysporum* f. *lycopersici*, but was not completely effective. It is necessary to avoid reinfestation as much as possible. In deeper layers of the soil the fungus is able to survive because the thermal death point of *F. oxysporum*, which is between 57.5° and 60 °C (Bollen, 1969), or the minimum required concentration of the fumigants for effective kill is not reached. The actual depth of effective disinfection also depends on soil factors. Disinfection by steaming, for instance, is better in summer

than in autumn or winter, because in summer the moisture content of the soil is lower and the initial soil temperature higher.

Our results with chloropicrin and methyl bromide correspond with those of Young (1940), Tobolsky and Wahl (1963), Perrotta and Cartia (1965).

The potential danger of conidia deposited on heating pipes and structural parts of the glasshouse as sources of soil reinfestation has been shown. Spraying with 4% formaldehyde proved effective, though the application of this disinfectant is most unpleasant for the machine operator. Moreover, growers dislike its corrosive action on iron parts. The experiments reported above, however, have not yielded an equally effective disinfectant, while the concentrations of gaseous methyl bromide or chloropicrin in the atmosphere of the glasshouse were insufficiently high to kill all dry macroconidia.

The control measures discussed will lose much of their efficacy if hygiene in other respects is neglected: elimination of all diseased plants (Introduction, item 9), disinfection of contaminated equipment or sites (items 3, 7, and 8) and use of new or disease-free materials when starting the next crop (items 4, 5, and 6) are necessary.

Sowing soil and potting soil (item 5) produced by specialized potting soil manufacturers has not proved contaminated at delivery. Neither has seed transmission been observed. Three years experience with *Fusarium* wilt of tomatoes and its control in the Netherlands has shown that the severity of the disease incidence per holding is reduced gradually when control measures are carried out carefully, although the number of holdings affected shows a steady increase.

Samenvatting

Ontsmetting van grond en kasopstanden ter bestrijding van Fusarium oxysporum f. lycopersici in tomaten in Nederland

In 1968 werd voor het eerst op enkele bedrijven in Nederland *Fusarium* verwelkingsziekte in tomaat waargenomen. De ziekte verspreidde zich snel in het volgende jaar.

Goede ontsmetting van een zandige grond blijkt mogelijk door nauwkeurige toediening van veel stoom (verbruik van 10 l stookolie per m^2), van chloorpicrine (60 ml/m^2) en van methylbromide (100 g/m^2) (zie Tabel 1).

Door beregening en bij het verwijderen van dode planten, waarop de schimmel sporuleert, worden veel conidiën afgezet op verwarmingsbuizen en kasvoeten. Per strekkende meter verwarmingsbuis werden 30.000 macroconidia gevonden. Ontsmetting hiervan met formaline gaf goede resultaten, maar met de systemische fungiciden uit de benzimidazol-groep niet (Tabel 2). De kasopstanden bleken niet ontsmet te worden door het methylbromide of chloorpicrine gas boven het plastiek bij de in de praktijk gebruikelijke grondontsmetting met deze middelen.

Voor een goede bestrijding van de schimmel is een grote bedrijfshygiëne vereist en dienen alle voor de produktie benodigde hulpmiddelen ontsmet te worden. In potgrond en zaaizaad is het pathogeen tot nu toe niet gevonden.

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Address

Laboratorium voor Bloembollenonderzoek, Heereweg 345a, Lisse, the Netherlands.

Book review

J. Horváth: Növényvírussok, vektorok, vírusátvitel (Plant viruses, vectors and virus transmission). 515 pp., 89 illustrations, 71 pp. of references, cloth bound. Akadémiai Kiadó, Budapest 1972. Price: Forint 92.

This handbook, written in Hungarian, mainly aims at surveying the rapidly expanding literature on plant viruses, and especially their transmission by vectors, for the benefit of Hungarian plant pathologists, biologists and crop protectionists. It is the first Hungarian textbook dealing with plant viruses. For that matter it starts with short chapters on the various aspects of general plant virology, each followed by a limited list of well-chosen recommended literature.

The main part of the book concerns virus transmission. After an introductory chapter on transmission and distribution of phytopathogenic viruses other chapters discuss the factors influencing relationships between viruses and their hosts and insect vectors, virus transmission by insect vectors and nematodes, other ways of transmission and distribution, viruses and mycoplasmas, and methods of studying virus-vector relationships.

The book contains an enormous amount of information, partly assembled into tables and extensive lists of vectors and the viruses they transmit. This is also reflected in the extensive list of references.

The book has been very well printed on high quality paper with many well-selected illustrations, photographs and drawings, most of them earlier published. In the author's home country this book will certainly meet a need.

L. Bos