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Dispersal of Phytophthora nicotianae on tomatoes grown by nutrient film technique in a greenhouse

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Abstract

Tomatoes were grown in a greenhouse by nutrient film technique (NFT). They were inoculated with *Phytophthora nicotianae* either by direct inoculation of roots or by adding fungal spores to a container with recirculating nutrient solution. In the first case, the resulting epidemic seemed to be polycyclic, in the second case monocyclic. In both cases, inoculum freely circulated through the NFT system and was present in the nutrient solutions for at least 6 days after inoculation.

Additional keywords: monocyclic epidemic, polycyclic epidemic.

Introduction

Nutrient film technique (NFT) is a relatively new way to grow plants without soil. Surplus nutrient solution can be dumped (drainage system) or recirculated (recycling system). The drainage system is uneconomical and polluting, the recirculation system may give phytohygienic problems. Davies (1981) and Evans (1977, 1979) feared rapid dispersal of pathogens, but Jeannequin (1981), Staunton (1978), and Staunton and Cormican (1978) did not. Obviously, more information is needed before large-scale application of the recirculation system can be recommended. Experiments were designed specifically to see whether or not pathogen dispersal by recirculating nutrient solution is possible. This paper reports the major results.

Material and methods

A NFT set-up in a greenhouse of the Institute of Agricultural Engineering (IMAG), Wageningen, was used with plastic covered metal troughs of 13 m length and 1 percent slope. The nutrient solution was stored in an open container of 300 l, from which the solution was pumped into the troughs. The solution slowly flowed down the troughs. The surplus was collected in the container.

Tomatoes (cv. Wilset TMC5F1F2RS) were sown in rockwool cubes (4 × 4 × 4 cm), which after 20 days were placed in the troughs at about 20 cm distances. Four days later, when the roots growing from the cubicles were at least two cm long, inoculation

took place with an isolate of *Phytophthora nicotianae* v. Breda de Haan. Two inoculation methods were applied. In Experiment 1 (E1), five plants per trough, from a total of 40 plants per trough, were inoculated by rubbing their roots with carborundum powder and placing the roots in a suspension of mycelial fragments and zoospores for 24 hours. This suspension was made by grinding cultures of *P. nicotianae* grown on oatmeal agar in a blender with distilled water. Before replacing the plants in the troughs the roots were thoroughly rinsed with tap water. In Experiment 2 (E2), a spore suspension was added to the container, giving a final density of 700 spores per ml nutrient solution.

Disease assessment was done regularly. The intensity of the disease was recorded per plant as the percentage of dead roots. The causal fungus was reisolated from diseased roots by means of the apple bait technique. Root fragments were placed in immature apples, cv. Cox Orange. The inoculated apples were incubated at 25 °C. When a lesion appeared, apple fragments including tissue from the margin of the lesion were transferred to oatmeal agar. When a mycelium appeared, the fungus was purified, identified and tested once more on tomato plants.

Samples of 500 ml were taken from the nutrient solution and checked for the presence of inoculum by a bioassay. The samples were passed over a micropore filter (pore size 1.2 μm). The filter, possibly with inoculum, was placed in a Petri dish and 10 ml distilled water was added. Roots of 10-week-old tomato plants were placed in the Petri dish during one hour. After exposure of the roots the plantlets were potted in steamed soil and incubated at 23 °C and high humidity. Five days later, the test plants were inspected for symptoms.

Results

Fig. 1 shows the development of the disease with time on the non-inoculated plants of E1 and on all plants of E2. Entries are averages from two troughs. In E1, in which only five plants per trough were inoculated, the first symptoms in non-inoculated plants were seen after six days (= one latency period + one incubation period). Inoculated plants became infectious after one latency period, and newly infected plants showed symptoms only after one incubation period. As the data suggest a polycyclic epidemic, a logistic curve was fitted to the data. The logistic infection rate was $r = 0.31$. In E2 the first symptoms were observed after 2 days (= one incubation period). As spores had been supplied to the circulating medium, an incubation period, but not a latency period, was needed to cover the time from infection to symptom expression.

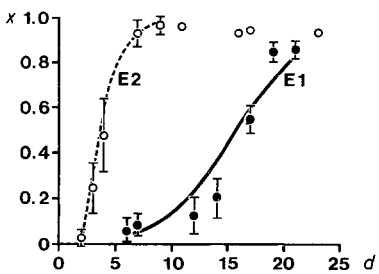

Fig. 1. Development in time of an epidemic of *P. nicotianae* on young tomato plants grown by nutrient film technique. Both curves represent the mean from two troughs. Horizontal: time d in days from inoculation. Vertical: proportion x of roots killed. E1 refers to Experiment 1, in which five plants per trough were inoculated. E2 refers to Experiment 2, in which inoculum was added to the nutrient solution tank. Vertical bars represent 10% confidence intervals.

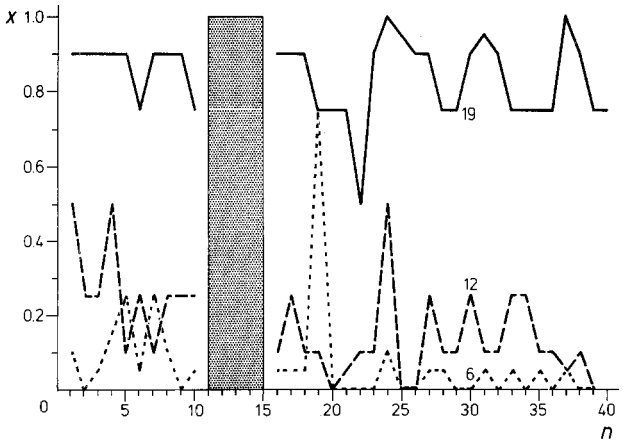

Fig. 2. Development in space of an epidemic of *P. nicotianae* on young tomato plants grown on nutrient film (Experiment 1). Horizontal: plant position *n;* plants were regularly spaced over the total length (13 m) of the troughs; nutrient solution flowed from left to right. Vertical: proportion *x* of roots browned by infection. Roots of plants at positions 11 through 15 (shaded area) were inoculated. Different curves represent results at 6, 12 and 19 days after inoculation. Each curve represents the mean from two troughs.

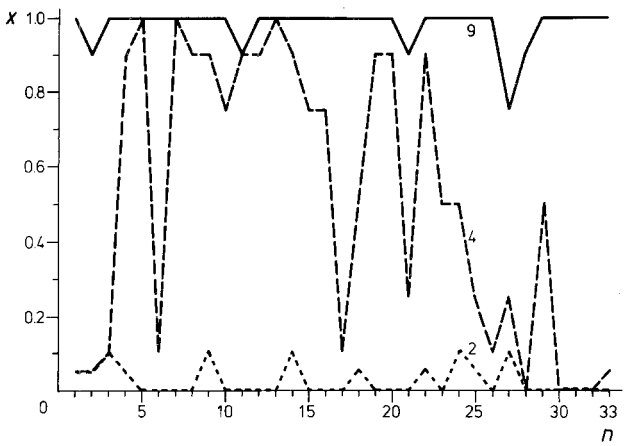

Fig. 3. Development in space of an epidemic of *P. nicotianae* on young tomato plants grown on nutrient film (Experiment 2). Horizontal: plant position *n;* plants were regularly spaced over the total length (13 m) of the troughs; nutrient solution flowed from left to right. Vertical: proportion *x* of roots browned by infection. Inoculum was added to the container with nutrient solution. Different curves represent results at 2, 4 and 9 days after inoculation. Each curve represents the mean from two troughs.

As the data here suggest a monocyclic epidemic, the 'simple interest curve' (Zadoks and Schein, 1979) was fitted to the data. The simple interest infection rate was r_s = 0.56.

Figs 2 and 3 show the development of the disease in space for E1 and E2. In E1 the

epidemic clearly started from the inoculated plants, but a typical focus was not formed. In E2, the disease was regularly distributed over the first half of the trough. In the experiments reported here, and in several others, the plants at the lower end of the troughs had less disease (significant at $p < 0.10$), at least in the beginning.

In E1, *P. nicotianae* could be reisolated from diseased roots of inoculated and non-inoculated plants; the fungus could be isolated from the nutrient solution up to 6 days after inoculation. In E2, *P. nicotianae* was reisolated from roots of dead and of surviving plants; the fungus was also isolated from the nutrient solution, frequently up to 11 days after adding inoculum to it and infrequently thereafter.

Discussion

All NFT experiments were done with replicate troughs. Only two experiments were selected to illustrate the major point: inoculum of *P. nicotianae* can circulate freely through the NFT system with the nutrient solution. Results on the type of epidemic generated, monocyclic versus polycyclic, were incidental. They are, however, of major importance to understand growers' risks.

The experimental conditions were for from ideal for tomatoes. As the experiment was performed in the autumn, light intensity was low. The greenhouse temperature (about 21 °C) was somewhat low for tomatoes. The plants showed symptoms of a mild iron deficiency. The positive result of the experiment may be due in part to the stress to which the plants were exposed. Experiment 2, repeated in various ways, indicated that *P. nicotianae* may kill 50% of the roots within 5 days and 50% of the plants within 18 days. Plants react to root death by forming new roots, so that occasionally the percentage of brown roots may decline.

Typical focus formation was expected but did not occur. For reasons unknown the plants at the lower end of the troughs remained relatively free from disease. When a few plants were inoculated, the epidemic seemed to have a polycyclic character. The time course of the disease progress curve was compatible with the idea of repeated (and probably overlapping) infection cycles of four to six days. When inoculum was added to the recirculation water, the epidemic had a monocyclic nature. Here, the time course of the epidemic was compatible with the idea that all plants, having the same probability of infection, differed in the rate of symptom development (Zadoks and Schein, 1979). The threatening nature of a monocyclic epidemic was confirmed inadvertently by an unexpected and unexplained spontaneous infection in one of the non-inoculated control troughs, which killed the roots rapidly. It should be noted that inoculum is known to be dispersed by irrigation water (Thung, 1938).

Various papers suggest spread of the fungus *Olpidium radicole* through greenhouses without soil, as inferred from disease symptoms caused by the virus it carries, but these papers are inconclusive as to the mechanism of spread (e.g. Bos et al., 1984; Thomas and Tomlinson, 1984; Tomlinson and Faithfull, 1984). Though the environmental conditions applied were slightly unusual, the present paper provides definite evidence of pathogen dispersal by recirculating nutrient solution.

Samenvatting

Verspreiding van Phytophthora nicotianae bij kastomaten gekweekt met de voedingsfilmtechniek

Kastomaten werden gekweekt met behulp van voedingsfilmtechniek. Zij werden geinoculeerd met *Phytophthora nicotianae* hetzij door directe besmetting van wortels, hetzij door een sporensuspensie toe te voegen aan het voorraadvat met voedingsoplossing. In het eerste geval leek een polycyclische epidemie te volgen. In het tweede geval ontstond een monomcyclische epidemie. In beide gevallen werd schimmelinoculum door het gehele gotensysteem rondgepompt. Inoculum bleef gedurende tenminste 6 dagen na inoculatie aantoonbaar in de voedingsoplossing.

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