Survey of Greenhouse Management Practices in Essex County, Ontario, in Relation to Fusarium Foot and Root Rot of Tomato

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ABSTRACT

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A survey of several management factors in an area densely populated with greenhouses in southwestern Ontario showed that few of the factors had a significant effect on the number of tomato crops affected by Fusarium foot and root rot caused by *Fusarium oxysporum* f. sp. *radicis-lycopersici*. No fully effective control measures could be identified, but it is recommended that soil fumigation or partial sterilization would be preferable to total sterilization by steam; that irrigation should be by warm water; that planting should be done in warm soil, either artificially warmed or late planted; and that mulching should be delayed to permit insolation. The incidence of the disease increased in the area since it was first seen in 1974. In 1978, 62% of the crops were affected.

Additional key words: *Lycopersicon esculentum*

Fusarium foot and root rot disease of tomatoes caused by *Fusarium oxysporum* f. sp. *radicis-lycopersici* (1) is serious and widespread in the greenhouse industries of Canada, the United States, and Japan (1,6). First seen in the Leamington area of Essex County, Ontario, in 1974, the disease rapidly became widespread and destructive (4). Although captafol has been used for control in Ohio greenhouses (5,6), the method of its application is difficult in Ontario because of the lack of overhead irrigation outlets and of underground tile ducts for soil steaming. The disease is characterized by the reentry of the pathogen as airborne microconidia to newly sterilized ground beds, which makes control difficult (5–7).

In 1978, spring tomato crops occupied 58.6 ha of glasshouses and 22.1 ha of plastic houses (Fig. 1). Typically two crops are raised annually. For the spring crop, seed is sown at the end of November; seedlings are transplanted to soil or peat blocks in December, then transplanted to steam-sterilized ground beds in early January. Fruit is picked from late March to July. The disease is most destructive in this spring crop and is less severe in the fall crop (June to December).

Seedlings are raised by a few specialist growers or by the crop producer. Similarly, soil and peat blocks are made in a few specialist houses, and they may or may not be steam-sterilized. The ground bed is invariably steam-sterilized just before the spring crop is transplanted, but steam sterilization may be omitted or replaced by fumigation before the fall crop.

This survey was undertaken to establish epidemiologic patterns of the disease in a densely populated greenhouse area and to identify cultural practices that predispose the plants to the disease or permit disease escape.

MATERIALS AND METHODS

The survey team visited 119 greenhouse ranges during the main production period, June–August, of the 1978 spring crop. Growers were interviewed regarding the history of disease in their crops, estimated losses, methods of production from seeding to trash disposal, methods of disease control, source and method of water application, method of mulching, and proximity of their greenhouse to neighboring greenhouses and to tomato fields. In addition, the survey team assessed the standard of hygiene in the greenhouse, headerhouse, and environs, observing trash piles, dirt on headerhouse floors (from which the causal organism could usually be isolated), and any other factors likely to contribute to spread or containment of the disease.

The data were processed by standard statistical procedures (usually χ^2 tests), with angular transformation where necessary. Significance was assessed at $P = 0.05$ unless stated otherwise.

The incidence of the disease within crops is largely based on growers' estimates, supported by counts made by the team in random areas in several greenhouses.

RESULTS AND DISCUSSION

History. The percentage of greenhouses in which the spring crop was affected rose each year: 1974, 23%; 1975, 37%; 1976, 47%; 1977, 57%; 1978, 62%. During this period, growers' estimates of annual crop loss ranged from 0 to 95%, with 66% of the estimates in the range of 0 to 4%.

This disease first appeared within a relatively small area and tended to spread to outlying greenhouses in succeeding years (Fig. 1).

In 1978, growers' estimates of the proportion of affected plants in the crop ranged from 0 to 60%, with 71% in the range of 0 to 4%. The mean incidence was estimated at 8%. Sixty-four percent of the total area in spring tomatoes was affected.

Varietal susceptibility. Forty of 48 (83%) crops of the pink-fruited cultivar MR13 were affected, 33 of 39 (85%) crops of WR25 (pink), six of 26 (23%) crops of Bruinsma Jumbo (red fruited), and one of five (20%) crops of Vendor (red fruited). Measured in this way, disease incidences in the pink MR13 and WR25, the main spring crops, were not significantly different, nor were disease occurrences in the red Bruinsma Jumbo and Vendor, late spring or fall crops, different from each other. When they compared them simultaneously, Jarvis and Thorpe (2) found the order of decreasing susceptibility to be Vendor >MR13 >WR25. The pink cultivars, however, were more affected (78/99, 79%) than the reds (9/37, 24%), probably because of the dominant production of the former in cool, early spring soils. The fungus has an optimum temperature for pathogenesis of about 18 C (1). Fifty-seven of 71 (80%) early spring crops, 20 of 42 (48%) late-planted spring crops, and two of 14 (14%) fall crops were affected. All differences were significant. Incidence of affected plants was significantly higher in early spring crops (5.2%) than in late spring (0.6%) and fall crops (0.2%).

Glasshouse vs. plastic house. From 1974 to 1977, an average of 63% of spring crops raised under glass were affected, with 78% affected in 1978; these figures compare with 29 and 33%, respectively, for crops in plastic houses. Differences may be related to planting date and thus to soil temperature: the later the planting, the warmer the soil.

Hygiene. The disease occurred in greenhouses of efficient and conscientious growers as well as of less efficient

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growers. This has been attributed to the ability of the pathogen, as airborne microconidia, to recolonize newly sterilized soil (7). The fungus was isolated readily from soil on headerhouse floors and from trash piles outside greenhouses; these areas were sources of airborne microconidia and of chlamydospores carried on feet and implements. Greenhouses were subjectively rated as excellent, good, fair, or poor with respect to general hygiene. The presence of trash piles was also recorded. The results of the headerhouse assessment were inconclusive; 7 of 11 (64%) in the excellent category were associated with disease in the greenhouse, 31 of 47 (66%) in the good category, 23 of 37 (62%) in the fair, and 3 of 5 (60%) in the poor category. Differences were not significant. A mean of 1.1% of plants was affected in the excellent category, 2.9% in the good category, 3.2% in the fair, and 4.7% in the poor category.

Similar results were obtained from a survey of the greenhouse exteriors. Disease was not especially associated with trash piles; 19 of 25 houses with trash piles outside had the disease.

Proximity of tomato fields. Although root rot has been artificially induced in field cultivars in Ontario (2), the disease has not been seen in commercial field crops there. Nevertheless, it is possible that field-grown plants could be symptomless or near-symptomless carriers of the pathogen. However, of 55 greenhouses (62%) adjacent to a tomato field, 34 had the disease, compared with 41 of 63 (65%) remote from fields. It seems unlikely, therefore, that field crops play a significant part, if any, in the epidemiology of the greenhouse disease.

Source of seedlings. In addition to many growers (50%) who raised their seedlings, two specialist growers supplied 20% of other growers, whereas the remainder of growers used seedlings of unknown origin. The disease was present in 54% of greenhouses where the growers had raised their own seedlings. Eight of 19 (42%) crops started by specialist growers and 16 of 25 (64%) crops of unknown origin were affected. These differences were not significant. According to growers' estimates, 2.3% of the plants supplied by one main specialist grower were affected and 4.4% of the plants supplied by the other main specialist grower.

There was no significant difference as to whether seedlings were raised under plastic or glass.

Seedling media. Seedlings were raised in wooden or plastic trays, approximately $60 \times 33 \times 7$ cm, filled with one of six media: peat-vermiculite, sand-peat, soil-peat, soil, sand, or peat. The soil was usually taken from the ground bed. The media were either sterilized or not; in some cases, that condition could not be ascertained. Neither sterilization of the seedling medium nor the nature of the medium had any effect on the incidence of the disease in the subsequent crops.

Transplants. Seedlings were transferred into four types of containers for transplant production: peat blocks with a small cavity, peat pots, plastic pots, or wood bands (four-sided wooden veneer structures enclosing a cube of soil or other potting medium, open at top and bottom). Each container was filled with soil (usually from the ground bed), or sand, or shredded peat, or a combination of these. The container and/or filling material was steam-sterilized or not. There were no significant differences in the presence of the disease in crops raised in the four main containers, whether sterilized or not. Similarly, there were no significant differences associated with the container-filling material, whether sterilized or not. The disease appeared in four of eight (50%) crops and in 3.2% of plants that were raised as transplants in sterilized sand, in three of five (60%) crops and 0.4% plants in unsterilized sand, in 16 of 20 (80%) crops and 5.9% plants in sterilized soil, in three of five (60%) crops and 0.5% plants in sterilized peat, and in 20 of 29 (69%) crops and 2.2% plants in unsterilized peat.

Five crops raised as transplants in individual plastic cups in trays (Speedling containers) escaped the disease in 1978.

Ground bed sterilization. When the disease first appeared in 1974, a priori reasoning called for sound hygiene control measures, including cleansing of the superstructure with formaldehyde solution. Somewhat surprisingly, experience then showed that some growers who practiced excellent hygiene sometimes had more disease in their crops than their less hygiene-minded neighbors. This can now be explained by rapid reentry of the pathogen to newly sterilized ground beds and perhaps to thick pieces of infested root debris that escape sterilization (6,7). Steam sterilizing is usually done from the surface of the ground bed in 2-m strips under plastic tarpaulins, and this was done by 28 growers. Twenty-four growers did this after first fumigating the soil; 16 steamed via buried clay tile ducts and seven steamed in that manner after fumigation. Five growers with only a fall tomato crop did not steam at all, and 16 growers used only fumigation before their fall crop.

Tile steaming only was followed by the disease in 14 of 16 (87%) crops with 3.0% of plants affected; surface steaming only, 20 of 28 (71%) crops with 4.6% plants; fumigation only, seven of 16 (44%) crops with 0.6% plants; fumigation and tile steaming, four of seven (57%) crops with 2.0% plants; fumigation and surface steaming, 17 of 24 (71%) crops with 2.1% plants affected. Significantly ($P = 0.01$) more crops were affected following tile steaming than following fumigation alone. Other differences were not significant. Five fall crops following cucumber crops with no prior soil sterilization were unaffected.

Formaldehyde washing. Growers who treated the superstructure with formaldehyde before and after ground bed sterilization all had their crops (16/16) affected by the disease; a mean of 5.4% of plants was affected. This compares with formaldehyde before sterilization: 17 of 23 (74%) with 4.4% plants affected. When formaldehyde was used afterward, five of

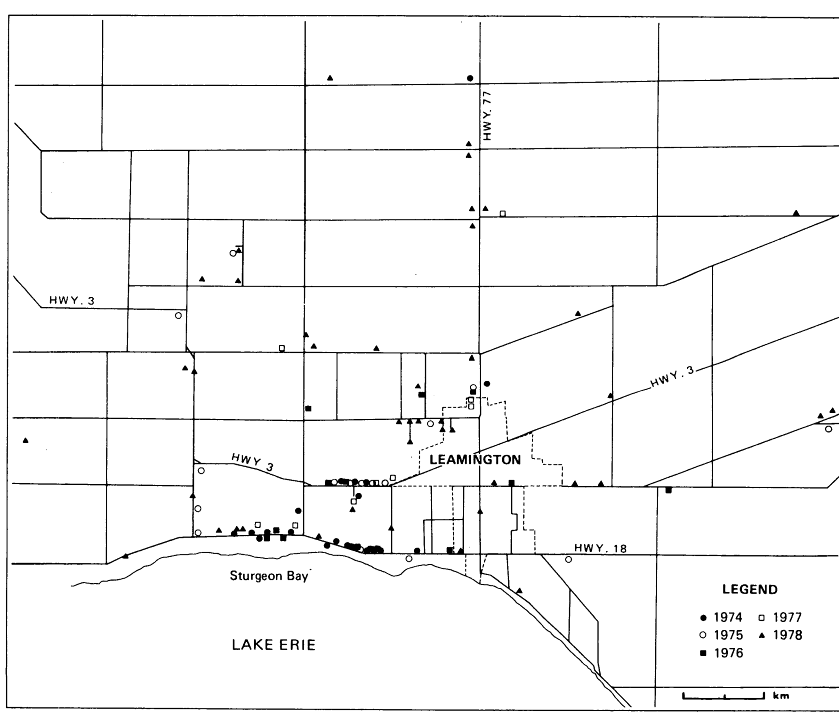

Fig. 1. Distribution of greenhouse tomato crops affected by Fusarium foot and root rot in the Leamington, Ontario, area, 1974–1978.

nine (56%) crops with 4.2% plants were affected, and when formaldehyde was not used at all 28 of 56 (50%) crops with 0.6% plants were affected. None of these differences was significant. Whether the formaldehyde was sprayed onto the superstructure or applied as a wash made no significant difference.

Fungicides. There is no recommended fungicide for Fusarium foot and root rot in Ontario, but many growers applied captafol (5) to newly sterilized ground beds. Benomyl was widely used as a drench and a spray in an attempt to control the disease, with little evident effect. Several other fungicides were used for other purposes, but none exerted any noticeable control.

Source of irrigation water. Several growers attributed the presence of the disease in their crops to a particular water source, ie, variously to their well, creek, or pond, or to the municipal water supply. Of the crops irrigated with municipal water, 36 of 48 (76%) were affected in 1978 with 7.2% plants affected, compared with 24 of 44 (55%) crops with 0.4% plants affected when irrigated with well water and four of 14 (29%) crops with 0.2% plants affected when irrigated from a pond or creek. Significantly more crops were affected, and more severely, when irrigated by municipal water than by water from wells (P = 0.05) or creeks (P = 0.01). It is possible that water temperature may have some effect on this low-temperature disease; the temperature of Lake Erie municipal water is about 4 C during the early part of the spring crop, whereas well water in the area is around 13 C for most of the year. The effect of these waters on soil temperature is unknown.

There was no difference in the incidence of the disease whether irrigated overhead or at ground level, the usual way.

Mulch. Crops are usually mulched with wheat straw or with ground-bed-incorporated farmyard manure, or both, with or without steam sterilization. With respect to straw, 24 of 30 (80%) crops (5.1% of plants) mulched with sterilized straw and 42 of 67 (63%) crops (2.2% of plants) mulched with unsterilized straw were affected. Six of 19 (32%) crops (0.3% of plants) with no straw mulch were affected, a significant advantage over sterilized straw-mulched crops (P = 0.01) and unsterilized straw mulch (P = 0.05). There was no advantage in sterilizing the straw. Thirty-one of 41 (76%) crops and 3.6% plants were affected when treated with sterilized manure, as against 19 of 28 (68%) crops and 4.4% plants when treated with unsterilized manure and 22 of 47 (47%) crops and 1.1% plants with no manure. Only the differences between the sterilized manure and the no-manure treatments were significant (P = 0.01). Treatments that insulate the cold soil early in the season tend to be associated with more affected crops, and it may be advantageous to delay straw mulching until soil temperatures are higher.

Soil type. The disease occurs in sawdust beds in British Columbia (R. G. Atkinson, *personal communication*), in heavy clay soils in Ohio (6), and in clay and various sandy soils in the Leamington area. A distribution map of affected greenhouses (Fig. 1) overlaying a soil map indicated no concentration of the disease in any one soil type. Soils are rarely brought into Essex County greenhouses.

Recommendations. Although no effective control measures were identified, the following four cultural practices could be recommended:

1. Ground bed sterilization methods, other than tile steam-sterilization alone, are recommended. Recent work (3) indicates that the disease is susceptible to biological control. For this reason, fumigation and partial soil sterilization would be more appropriate.
2. Excessive hygiene in the greenhouse is not beneficial.
3. Water from cold reservoirs should not be used for irrigation before warming.
4. Ground bed soil should be warm at the time of planting. This can be accomplished by planting later in the spring; warming the soil, eg, by passing steam briefly through buried tile ducts; or delaying the placement of straw or manure mulches to permit insolation of the ground bed. There is no advantage in sterilizing the mulch material.

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