A survey of penicillium stem rot on greenhouse cucumbers in southwestern Ontario

W.R. Jarvis[1] *and G.M. Ferguson*[2]

In 1991, a field survey was conducted in 57 commercial greenhouses of southwestern Ontario as a preliminary action for the rational design of control measures for penicillium stem rot *(Penicillium oxalicum)* of greenhouse cucumbers. The disease was more prevalent in the Niagara area compared to the Leamington area (100% of crops affected versus 46%); it was more prevalent in medium-sired houses than large or small greenhouses; crops grown in rockwool (46%) were more affected than crops grown in soil or soil mix (21%); and the incidence of the disease was associated significantly with gummy stem blight *(Didymella bryoniae)* in spring crops, but not fall crops. No cultivar differences in susceptibility to penicillium stem rot were found. Isolates of Penicillium *oxalicum* (86% of those tested) were resistant to benomyl and two isolates were resistant to iprodione and cross-resistant to benomyl.

Can. Plant Dis. Surv. 72:2, 103–106, 1992.

En 1991, une evaluation préliminaire a été menée dans cinquante-sept serres commercialles au sud ouest de l'Ontario pour le modele des mesures de lutte contre la pourriture de la tige du concombre de serre *(Penicillium oxalicum).* La maladie a été plus predominante dans la region du Niagara que dans la region de Leamington (100% des cultures ont ete infectees versus 46 %); elle a ete plus prédominante dans les serres de dimension moyenne que dans les serres de dimension plus grande ou plus petite; les cultures produites sur laine de roche ont ete plus affectees que les cultures produites dans le sol ou un melange de sol (21%); et, l'incidence de la maladie a été associee de façon significative avec *Didymella bryoniae* dans les cultures de printemps mais pas dans les cultures d'automne. Aucune difference entre les cultivars n'a ete trouvee concernant la suceptibilité à *Penicillium oxalicum.* Quatre-vingt-six pourcent des isolats de *Penicillium oxalicum* evalues ont ete resistants au benomyl et deux isolats ont ete resistants a l'iprodione. Ces deux isolats ont eu, aussi, une resistance croisee pour le bénomyl.

Introduction

The first report of penicillium stem rot of greenhouse cucumbers was from crops in the Leamington area of southwestern Ontario in 1988 (4). The causal organism was first designated as *Penicillium crustosum* Thom but subsequent work showed it to be *P. oxalicum* Currie & Thom (5). The disease has also been reported in England (7), the Netherlands and Scandinavia (8). Little is known of the factors determining the rise of *P. oxalicum* as a widespread and severe pathogen of both stems and fruit of greenhouse cucumbers (4,5,7,8). The survey reported here was undertaken to identify which, if any, of the current greenhouse cropping practices could be associated with incidence and severity of the disease.

Materials and methods

Fifty-seven growers' properties in the Leamington area of southwestern Ontario were surveyed by scouts in May and June, 1991, to monitor the spring crop and to obtain information from the grower on cropping and disease history. In addition, eight growers (about 28% in the Niagara area were visited, and information was obtained on 23 crops in all there. The growers were asked a number of questions designed to identify possible predisposing factors, as well as to obtain their estimates of the incidence and severity of the disease. The scouts inspected and collected samples of the crop to confirm whether or not the grower had identified the disease correctly. The early symptoms of penicillium stem rot *(Penicillium oxalicum),* grey mould *(Botrytis cinerea* Pers.: Fr.), gummy stem blight *(Didymella bryoniae* (Auersw.) Rehm), and white mould (*Sclerotinia sclerotiorum* (Lib.) de Bary) can be superficially similar, but most experienced growers seemed to have [identified penicillium stem rot correctly. Powdery mildew (*Sphaerotheca fuliginea* (Schlechtend.: Fr.) Pollacci) and pythium root rot (various *Pythium* spp.) were also observed at the sites.

Plant material with symptoms of *P. oxalicum, B. cinerea, D. bryoniae* or *S. sclerotiorum* was brought back to the laboratory, and spores, when present, were streaked directly on potato dextrose agar containing 0.1 μg/ml benomyl as Benlate 50 WP® or 0.2 μg/ml iprodione as Rovral 50 WP®. Growth of the pathogens at those concentrations of fungicides was taken as indicative of resistance (6). Fungi not sporulating when collected were induced to do so by incu-

1 Agriculture Canada Research Station, Harrow, Ontario, Canada NOR 1G0.
2 Ontario Ministry of Agriculture and Food, Harrow, Ontario, Canada NOR 1G0.
Accepted for publication February 12, 1992.

bating the material in a moist chamber for one or two days, and S. *sclerotiorum* was isolated directly from the coplous mycelium.

All data were analyzed using chi-square tests. The factors tested for a significant association with penicillium stem rot were:

Region (Leamington vs. Niagara)
Size of greenhouse range
Growing medium (soil vs. rockwool)
Association with other commonly occurring diseases
Cultivar
Type of cover (glass vs. plastic)
Season (spring crop vs. fall crop)
Sanitation measures
Type of pesticide application equipment
Number of fungicide applications
Greenhouse environment control (manual vs. computerized)

In the case of soil groundbeds, differences in soil type were not taken into account since greenhouse soils have been considerably modified over many years by heavy amendments of organic materials. Significant associations were found in the first four factors; none of the other factors were signifcantly associated with the incidence of penicillium stem rot at $P = 0.05$.

Results

Factors significantly associated with penicillium stem rot

Region. Each of 23 crops surveyed in the Niagara area was affected by penicillium stem rot, whereas 38 of 83 crops (46%) in the Leamington area (Essex County) were affected, a difference significant at $P = 0.01$. All the growers in the Leamington area were surveyed, and although only 28% of the Niagara area growers were visited, the sampled sites appeared highly representative based on reports of other commercial growers in the area and of extension personnel familiar with the growers and their disease problems.

Size of greenhouse range. Greenhouse ranges were grouped into three size categories: (1) 0.25 - 0.50 ha (small), (2) 0.60 - 1.0 ha (medium) and (3) >1.0 ha (large). There was significantly more ($P = 0.05$) penicillium stem rot in ranges of medium size than in smaller or larger ranges, but only for the spring crop. The disease was present in 18 (70%) medium sized greenhouses, in five (38%) large, and in five (33%) small greenhouses.

Growing medium. Of the two principal growing media, soil and rockwool, a highly significant association ($P = 0.001$) was found for rockwool (Tables 1 and 2). In the spring crop, a mean of 44% of crops grown in rockwool had stem rot, in contrast to 17.4% of crops grown in soil. Similarly, in the fall, 48.2% of the crops grown in rockwool were diseased, against 14.3% grown in soil.

Association with other commonly occuring diseases. Penicillium stem rot was significantly associated ($P = 0.001$) with gummy stem blight in all of the spring crops but in only 35% of the fall crops. There was no association of penicillium stem rot with incidence of pythium root rot, grey mould and powdery mildew in either the spring or fall crop.

Factors not significantly associated with penicillium stem rot

Season. The incidence of penicillium stem rot in spring crops was compared with that in fall crops. Thirty-three percent and 45% of spring and fall crops, respectively, had the disease (Tables 1 and 2).

Type of cover. Only glass and plastic (double polyethylene) houses were encountered; there were no glasshouses with a plastic liner. Penicillium stem rot was present in 43% and 49% of the glass and plastic houses respectively.

Cultivar. Only the two most commonly grown cultivars, Corona and Jessica, were considered for analysis (Tables 1 and 2). Thirty-six percent and 37% of Corona and Jessica crops, respectively, had penicillium stem rot.

Table 1. Incidence of penicillium stem rot in spring greenhouse cucumber crops by substrate and cultivar.

Substrate	Cultivar					
	Corona	Jessica	Bronco	Sandra	Dugan	Venlura
Rockwool	15/33[1]	8/19	3/6	4/8	0/0	0/2
Oasis	0/1	1/4	0/0	1/3	0/0	0/1
Soil	5/25	2/12	1/5	0/3	0/0	0/1
Soil/Peat	0/1	1/1	0/0	1/2	0/0	0/0
Peat	0/1	0/0	0/0	0/0	0/0	0/0

1 Affected/total crops.

Sanitation measures. Sanitation procedures such as sterilization of rockwool bags, changing of plastic ground cover, steaming vs. fumigation of soil, site location (upwind, downwind) and distance of trash dumping, from the production greenhouse, were factors considered. The disease was present in 30% of those houses where growers used the municipal dump site, and 50% of those where dumping of crop debris was done in the environs of the greenhouse. No contributing factor could be identified.

Of all the growers surveyed, 65% sterilized their rockwool bags, 70% sterilized irrigation drippers, and 66% changed their plastic ground cover; all equally had penicillium stem rot in their crops. Steaming is usually practised for rockwool and fumigation with methyl bromide for soil. Thirteen percent of the crops grown in a steamed soil, and 20% of those grown in fumigated soil had penicillium stem rot.

A straw mulch, steam-sterilized or not, did not affect the disease incidence when it was applied to crops in soil.

Type of pesticide application equipment. Low volume fogging machines were compared with high volume sprayers. Penicillium stem rot was equally present in houses using either one of these two types of equipment, the disease was in 59% of houses with low-volume and 52% of those using high-volume equipment.

Number of fungicide applications. Growers were separated into four categories according to the number of fungicide applications made: (1) <10, (2) 11-20, (3) 21-30, and (4) >30. Penicillium stem rot was present in 17 of 25 crops (68%) of growers who had applied less than ten fungicide sprays, seven of eight crops (88%) receiving between 10-20 sprays, two of two (100%) receiving 21-30 sprays, and in seven of ten crops (70%) with >30 sprays.

Environmental control. Automation of environmental control appeared to have had no effect on penicillium stem rot incidence, the disease being present in 50% of the houses that had computer-controlled enwironments, and 48% that had manual control.

Resistance of pathogens to fungicides

Results of *in vitro* assays of isolates of *P. oxalicum, Botrytis cinerea* and *Didymella bryoniae* are summarized in Table 3.

Cross resistance to both benomyl and iprodione was found in two isolates of *P. oxalicum* and one of *B. cinerea.*

Discussion

Four main factors affecting the incidence and severity of penicillium stem rot of cucumbers were identified. There were significantly more crops affected, and by the growers' estimates, more severely affected, in the Niagara area than in the Leamington area; more crops in medium-sized houses (0.6 - 1.0 ha) were affected than in smaller or larger houses; and crops in rockwool were more likely to be affected and more severely so, than crops in soil; and penicillium

Table 2. Incidence of penicillium stem rot in fall greenhouse cucumber crops by substrate and cultivar.

Substrate	Cultivar					
	Corona	Jessica	Bronco	Sandra	Dugan	Ventura
Rockwool	8/16[1]	10121	418	1/2	418	0/1
Oasis	0/0	0/1	0/0	0/0	0/0	0/0
Soil	1/3	012	0/0	0/1	0/0	0/1
Soil/Peat	0/0	1/2	0/0	1/2	0/0	0/0
Peat	0/0	0/0	0/0	0/0	0/0	0/0

1 Affected/total crops.

Table 3. *In vitro* resistance of fungal isolates to benomyl (1 μg/ml) and iprodione (2 μg/ml).

	Benomyl		Iprodione	
	Resistant	Susceptible	Resistant	Susceptible
Penicillium oxalicum	19 (86%)	3 (14%)	2 (9%)	20 (91%)
Didymella bryoniae	32 (73%)	12 (27%)	0	43 (100%)
Sotrytis cinerea	10 (42%)	13 (58%)	1 (4%)	22 (96%)

stem rot was significantly associated with gummy stem blight in the spring crop, but not in the fall crop.

Region. Growers in the Niagara and Leamington areas broadly follow Provincial recommendations (1,2). We are unable to suggest why the disease was more prevalent and severe in the Niagara area, with its rather more diffuse distribution of greenhouses, than in the dense concentration of greenhouses in the Leamington area. There may have been climatic differences between the two areas, which are about 400 km apart, but we have not yet been able to identify them.

Size of greenhouse range. The size of the greenhouse may well affect its microclimate, but this factor is likely to be overridden by variations in temperature control, humidity control, ventilation, air movement, irrigation systems, ground cover and perhaps several other imponderable factors. Although there may be slight variations in plant density and pruning systems, they are not likely to be affected by house size.

Growing medium. Crops in rockwool are more likely to be affected, and more severely so, than crops in soil, which strongly suggests that stress may well be a predisposing factor. In general, crops in rockwool are more precisely controlled by nutrition and yield 10 - 30% more than crops in soil (W.A. Straver, personal communication). Alternatively or additionally there may be nutrients, for example, silicon, available in most soils, but not in rockwool, that might have conferred resistance. We are therefore unable to explain this effect.

Association with other commonly occuring diseases. That penicillium stem rot is associated with gummy stem blight in the spring crop suggests similar predisposing conditions; the temperature and humidity conditions in the spring may be similar for the two diseases. Van Steekelenburg and van de Vooren (9) associated the presence of gummy stem blight in the spring crop with low night temperatures (12 - 16°C), at a constant day temperature of 23°C in a preinoculation period. In the fall crop, there were no significant differences between temperature regimes. Plants grown under drier conditions were less affected by gummy stem blight, but grey mould and powdery mildew were more evident under drier than humid conditions.

Sanitation. No major breach in sanitation procedures could be found that might have explained the distribution and severity of the disease. The source of inoculum remains obscure.

The finding of resistance to the fungicides benomyl and iprodione in *B. cinerea* and *D. bryoniae* underlines the necessity to rely on environmental control of grey mould and gummy stem blight rather than fungicides. The high incidence (86%) of isolates of *P. oxalicum* resistant to benomyl may well mean that penicillium stem rot is an iatrogenic disease (3), exacerbated by benomyl.

It is noteworthy that O'Neill *et al.* (7) also found United Kingdom isolates of *P. oxalicum* to be resistant to 2 μg/ml, as well as to 20 μg/ml benomyl.

Acknowledgements

We gratefully acknowledge the financial assistance of the Ontario Ministry of Agriculture and Food, Pest Management Research Program, Food Systems 2002. We thank Susan Barrie, Jane Kochan, Stefania Ligori, and Theresa Shonfield for excellent technical assistance, and Ms. Gretchen Shantz and Mr. W.A. Straver for information. We also thank the many growers who cooperated in the survey and provided valuable information, samples and suggestions.

Literature cited

1. Anonymous. 1988. Growing greenhouse vegetables. Ontario Ministry of Agriculture and Food (OMAF) Publication 526.
2. Anonymous. 1990. Pest management recommendations for Ontario greenhouse crops. Ontario Ministry of Agriculture and Food (OMAF) Publication 365.
3. Griffiths, E. 1981. Iatrogenic plant diseases. Annu. Rev. Phytopathol. 19:69-82.
4. Jarvis, W.R. and Barrie, S.D. 1988. Stem rot of greenhouse cucumbers caused by *Penicillium crustosum.* Plant Dis. 72:363.
5. Jarvis, W.R., Barrie, S.D., Traquair, J.A. and Stoessl, A. 1990. Morphological and chemical studies of *Penicillium oxalicum,* newly identified as a pathogen on greenhouse cucumbers. Can. J. Bot. 68:21-25.
6. Northover, J. and Matteoni, A.J. 1986. Resistance of *Botrytis cinerea* to benomyl and iprodione in vineyards and greenhouses after exposure to the fungicides alone or mixed with captan. Plant Dis. 70:398-402.
7. O'Neill, T.M., Bagabe, M. and Ann, D.M. 1991. Aspects of biology and control of a stem rot of cucumber caused by *Penicillium oxalicum.* Plant Pathol. 40:78-84.
8. Van Steekelenburg, N.A.M. 1988. Penicillium steekt in toenemende mate de kop op. Weekblad Groeriten en Fruit, November 18:41.
9. Van Steekelenburg, N A.M. and van de Vooren, J 1980. Influence of glasshouse climate on development of diseases in a cucumber crop with special reference to stem and fruit rot caused by *Didymella bryoniae.* Acta Hortic. 118:48-58.