INFLUENCE OF THE GLASSHOUSE CLIMATE ON DEVELOPMENT OF DISEASES IN A CUCUMBER CROP WITH SPECIAL REFERENCE TO STEM AND FRUIT ROT CAUSED BY DIDYMELLA BRYONIAE

N.A.M. van Steekelenburg
Research Institute for Plant Protection (IPO),
Wageningen,
Seconded to the Glasshouse Crops Research and Experiment Station,
Naaldwijk,
The Netherlands

J. van de Vooren
Glasshouse Crops Research and Experiment Station,
Naaldwijk,
The Netherlands

Abstract

In an autumn crop of cucumber no significant differences in disease development of D. bryoniae were observed between three temperature regimes and time of transition from night to day conditions. Plants grown under drier conditions were less affected than plants under more humid conditions. Powdery mildew was more severe under drier conditions.
In a spring crop the disease incidence was higher on plants grown at lower night temperatures in the pre-inoculation period. Once D. bryoniae had been established in the crop the development of the disease passed on parallel. The incidence of D. bryoniae was lower and of Botrytis cinerea higher under drier than under more humid conditions.

Introduction

Didymella bryoniae (Auersw.) Rehm, synonyms: Mycosphaerella citrullina (C.O. Sm.) Gross. and Mycosphaerella melonis (Pass.) Chiu and Walker, does occur every year in every glasshouse with a cucumber crop in the Netherlands. The disease is known as fruit and stem rot, black fruit rot and gummy stem blight. Losses vary from nursery to nursery and from time to time. Most damage is done by fruit infection from May and later on in the season. The lesions with black fruiting bodies, just visible to the naked eye as black dots, on the stubs left after removal of the fruits are the most characteristic symptoms of the disease. These lesions can progress on the main stem.
Control of the disease by spraying fungicides is difficult (Van Steekelenburg, 1978). Some resistance in certain cucumber lines has been found (Van de Meer et al., 1978), but resistant cultivars suitable for Dutch conditions are not yet available. In practice and in inoculation experiments with young plants it was shown that humid conditions favour the disease. This was one of the reasons to study the influence of the climate on disease development in cucumber crops grown in a commercial way. The increase of costs of energy in the recent years forces the glasshouse industry to bring down these costs and to minimize the waste of energy. Therefore is was necessary to study the effect of ventilating less than usual and of lower temperature regimes on the development of diseases.

Materials and methods

The influence of the glasshouse climate on disease development has been studied in two cucumber crops in the 24 compartments of a glasshouse with a computer controlled climate (Van de Vooren and Koppe, 1975).

The first experiment was with an autumn crop in 1976 and the second one with a spring crop in 1979, both with cultivar Farbio. Plants were grown, while the side-shoots were taken away, until they reached the wire at about 2.1 m above soil level. Then the growing tip was removed and two side-shoots were allowed to grow down from the top. Powdery mildew was controlled by regu larly spraying of pyrazophos ('Curamil') or ditalimfos ('Plondrel'). In some treatments the closing of the ventilators was prevented by a minimum ventilator opening of 0 to 10% depending on outdoor conditions. The inoculum of D. bryoniae was prepared by growing the fungus for two weeks on cherry decoction agar under black light (Philips TL 20W F20 T12 BLB) to induce sporulation. The conidia were washed off with water and each plant was sprayed under high pressure with about 0.3 l suspension with a concentration of 10^5 conidia per millilitre. The numer of lesions on the main stem were counted several times during the experiments to characterize the disease development. The fruits were harvested twice a week and any suspect fruit was cut in half lengthwise to check for internal rot.

Autumn crop

Cucumbers were planted in six rows each of eleven plants in each glasshouse compartment in mid June. The setting of the climate was divided into two periods:

- In the first period, the first five weeks after planting, two different regimes each in twelve replicates were set in order to obtain "sturdy" and "weak" plants. Sturdy plants were obtained by irrigating three times a week as little as possible, a minimum ventilator setting and a minimum water temperature of the heating system of 30°C. Weak plants were obtained by daily irrigating and no limitations on ventilation and water temperature. The temperature regime was 21/23°C (night /day).
- In the second period, at the start of production, different climate regimes were set in order to obtain variations in humidity. The temperature regimes were 18/23, 21/23 and 21/21°C. Transition from night to day was set one hour before or one hour after sunrise. So there were two replicates of both sturdy and weak plants.

At the beginning of the second period half of each compartment (three rows) was inoculated once. The crop was finished at the end of September, ten weeks after inoculation.

Spring crop

This experiment was set up to study the effect of day/night temperature regimes on growth of cucumbers, earliness, production rate (see Van de Vooren, 1980) and on disease development. Observations were made on 40 plants per compartment with a planting date end of December. The setting of the climate was divided into three periods:

- In the first period, the first eight weeks after planting, there were eight temperature regimes (see table 5) in three replicates.
- In the second period, the following six weeks, the temperature regime was 16/23°C.
- In the third period, the three replicates of the first period got a different climate regime in order to obtain different humidity conditions. The transition from night to day temperature and the ventilator setting were as follows:
  1. slow transition over a period of four hours starting two hours before sunrise and no minimum ventilation.

2. quick transition in the shortest period possible starting half an hour before sunrise and no minimum ventilation.
3. normal transition in half an hour starting at sunrise and a minimum ventilation.

In the treatments with no minimum ventilation the ventilators were closed when the air temperature was raised till three hours after sunrise. In the third period, the foliage was inoculated three times with intervals of two weeks. The crop was finished at the end of June, ten weeks after the first inoculation.

Results

The first symptoms of the disease, small yellow and necrotic lesions in young leaves, could be observed about one week after inoculation. Diseased stubs in leaf axils could be observed about two weeks after inoculation. The first fruits with internal rot were found seven to ten days after inoculation.

Autumn crop

The percentages diseased leaf axils of the main stem at the end of the crop are given in table 1. The disease development during the experiment on inoculated and non-inoculated sturdy and weak plants is given in fig. 1. The spread of the disease from inoculated to uninoculated sturdy and weak plants is given in table 2. The percentage infected fruits varied from harvesting date to harvesting date. The highest percentage infected fruits on a harvesting date was nearly 7% with inoculated weak plants. The average percentages fruits with internal rot in the period in which this symptom occurred are given in table 3. The differences in yield between non-inoculated and inoculated plants and between weak and sturdy plants are given in table 4.

Healthy looking fruits of two cropping dates, about 1000 fruits on each date, were stored at 20°C under humid conditions under a plastic sheet for two weeks. External fruit rot was found on 1.0% and 3.2% of the fruits of these two dates respectively. About 70% of the infected fruits were from weak plants and 30% from sturdy plants. There was no correlation between external fruit rot and temperature regime or time of the night-day temperature change. Of the fruits judged healthy of these two storages 0.2% and 1.0% showed internal rot.

The number of lesions on the main stem due to a natural infection of Botrytis cinerea (grey mould) were counted at the end of the crop. There was only an average of 0.3 lesions per plant. No significant differences between treatments did occur.

No mildewicide was sprayed in the last few weeks of the experiment. More than 50% of the surface of many leaves of sturdy plants was colonised by powdery mildew at the end of the crop. Weak plants had only some small colonies on a few leaves. No significant differences were observed between the other treatments.

Spring crop

Since the number of leaves on the main stem differed between the treatments, percentages diseased leaf axils are given in tables and figures. The disease incidence at the end of the crop is given in table 5. The disease development during this experiment is given in fig. 2 and 3. The first two fruits with internal rot were found nine days after the first inoculation. The percentage infected fruits increased to 14% twenty days after the first inoculation, then decreased to 5% and in-

creased subsequently to 13% thirty days after the second inoculation. No pattern was observed later on. The average percentages of internally rotten fruits in the period in which this symptom occurred are given in table 6. No significant differences in yield did occur between the three treatments with different humidity conditions.
A natural infection of leaf axils caused by Botrytis cinerea was observed in the last two months of the experiment. The Botrytis lesions on the main stem were counted four times with intervals of two weeks. The percentage infected leaf axils doubled in these two months (fig. 4). The incidence of Botrytis at the end of the crop is given in table 7.

Conclusions and discussion

In the autumn crop no significant differences in disease incidence between the temperature regimes and between the time of the night-day temperature change in the post-inoculation period was observed. Sturdy plants which were grown with minimum ventilator and minimum heating settings were significantly less affected than weak plants which were grown without minimum ventilator and heating settings (table 1). The spread of the disease to non-inoculated plants was quicker on weak than on sturdy plants (table 2). Fruits from sturdy plants were also significantly less affected internally (table 3) and externally than fruits from weak plants. However, sturdy plants produced obviously fewer healthy fruits than weak plants, especially on the side shoots (table 4). A high incidence of D. bryoniae reduced the number of healthy fruits. The incidence of D. bryoniae was not high in the period in which the fruits of the main stem were picked but still the number of healthy fruits was higher from non-inoculated than from inoculated plants. This difference was doubled, however, in the period in which the fruits from the side shoots were picked and a severe incidence of the disease occurred (table 4).
In the spring crop there was a postponed effect of the night temperature maintained during the pre-inoculation period on the disease incidence on the main stem later on in the season. The disease was more severe on plants grown at lower night temperatures in the pre-inoculation period (table 5). The day temperature in the pre-inoculation period had no effect on the incidence of D. bryoniae lesions later on in the season. Differences in percentage internal fruit rot were too small to observe significant differences between climate regimes (table 6).
The differences in disease incidence on the main stem in the spring crop were not as substantial as in the autumn crop. This explains probably that in the spring crop no effect of climate regimes on internal fruit rot could be found. A possible reduction in yield due to a D. bryoniae infection could not be established either in the spring crop. The percentage of fruits with internal rot was much higher in the spring crop than in the autumn crop. This may partly be a direct effect of the spraying of the conidial suspension. The autumn crop was inoculated once and the spring crop three times. However, the curve of the percentages of infected fruits during the experiment did not have peaks with the same time interval of two weeks as the three inoculations. The first peak, about 20 days after the first inoculation, indicates that fruit infection takes place in the flowering period.
The outbreak of D. bryoniae was favoured by humid conditions in the autumn crop. The daily maximum relative humidity was about 10% lower in the treatments with a minimum ventilator opening than in the treatments without it. The same tendency was found in the spring crop although

differences in disease incidence were not great. Once D. bryoniae being established in the spring crop the development of the disease passed on parallel (fig. 3). So to control the disease the main emphasis must be on preventing its establishment in the crop.
The outbreak of powdery mildew was more severe in the treatments with minimum ventilator and heating settings, so under drier conditions. This confirms the results obtained by Abiko and Kishi (1979).
The incidence of grey mould, Botrytis cinerea, was very low. Contrary to D. bryoniae it was most severe on plants grown at a temperature regime of 16/17°C in the first period after planting. The development of the plants in this treatment was disturbed amongst others by fasciation and the development of many fruits per leaf axil. Many fruits aborted and as Botrytis is known to infect plants via dead parts this may explain the high incidence of Botrytis in this treatment. Less grey mould was observed in the treatments with high night temperatures during the first period after planting as was found with D. bryoniae. Contrary to D. bryoniae the incidence of B. cinerea was most severe in the treatment with a minimum opening of the ventilators. The conclusions regardering B. cinerea have to be chequed in crops inoculated with this pathogen.
It is a matter of economics to calculate whether it is profitable to grow plants at lower temperatures and at higher humidities. In this economical model the risk of outbreaks of pathogens must be included. The results obtained so far indicate that it is possible to grow glasshouse cucumbers at lower temperature regimes and at higher humidities than in the past without getting great problems with fruit and stem rot, grey mould and powdery mildew.

Acknowledgements

Special thanks are due to S.J. Paternotte and P. van Sabben for their help in carrying out the experiments.

References

Abiko, K. and Kishi, K., 1979. Influence of temperature and humidity on the outbreak of cucumber powdery mildew. Bull. Veg. & Ornam. Crops Res. Stat. Japan A 5 : 167-176.
Meer, Q.P. van der, Bennekom, J.L. van and Giessen, A.C. van der, 1978. Gummy stem blight resistance of cucumbers (Cucumis sativus L.). Euphytica 27: 861-864.
Steekelenburg, N.A.M. van, 1978. Chemical control of Didymella bryoniae in cucumbers. Neth. J. Pl. Path. 84: 27-34.
Vooren, J. van de, 1980. Effect of day and night temperature on earliness and fruit production. Acta Hort. 118 (in press).
Vooren, J. van de and Koppe, R., 1975. The climate glasshouse at Naaldwijk. Neth. J. Agr. Sci. 23: 238-247.

Table 1 - Percentages leaf axils of the main stem with D. bryoniae lesions at the end of an autumn crop of cucumbers with different plant types, grown at different climate regimes (33 plants per treatment in 2 replicates).

Plant type	Night-day temperature in °C	Transition before (B) or after (A) sunrise	Non-inoculated plants	Inoculated plants
Sturdy	18-23	B	16	48
Sturdy	18-23	A	14	41
Sturdy	21-23	B	11	44
Sturdy	21-23	A	13	37
Sturdy	21-21	B	13	45
Sturdy	21-21	A	17	53
Weak	18-23	B	44	65
Weak	18-23	A	41	70
Weak	21-23	B	44	61
Weak	21-23	A	43	62
Weak	21-21	B	35	53
Weak	21-21	A	33	63

Table 2 - Spread of D. bryoniae from inoculated (A, B and C) to uninoculated rows of plants (D, E and F) in an autumn crop of cucumbers. Mean percentages leaf axils of the main stem with D. bryoniae lesions (11 plants per row; 12 replicates).

Plant type	Weeks after inoculation	Row					
		A	B	C	D	E	F
Sturdy	2	7	7	4	0	0	0
Sturdy	5	27	29	27	7	0	0
Sturdy	10	47	51	46	14	11	11
Weak	2	11	11	11	0	0	0
Weak	5	40	46	43	18	7	7
Weak	10	61	68	64	47	37	36

Table 3 - Number and percentages of internally rotten fruits by D. bryoniae on non-inoculated and inoculated plants of an autumn crop of cucumbers grown at different climate regimes (396 or 264 plants per treatment).

Treatment		non-inoculated plants		inoculated plants	
		number	%	number	%
Sturdy plants		62	0.9	182	2.6
Weak plants		172	2.2	325	4.3
Night-day temperature change	1 h before sunrise	130	1.7	281	3.8
	1 h after sunrise	104	1.4	226	3.2
Night-day temperature	18-23	91	1.8	167	3.4
	21-23	71	1.5	166	3.6
	21-21	72	1.5	174	3.5

Table 4 - Differences in number and in percentage of not by D. bryoniae infected fruits between non-inoculated (N) and D. bryoniae inoculated (I) plants and between weak (W) and sturdy (S) plants (792 plants per treatment).

Harvesting period	N - I		W - S	
	number	%	number	%
Stem fruits	325	4.4	-203	-2.9
Side shoot fruits	856	9.1	+1666	+16.8
All fruits	1181	7.0	+1463	+ 8.6

Table 5 - Percentages leaf axils of the main stem with D. bryoniae lesions at the end of a spring crop of cucumbers with different temperature regimes in the pre-inoculation period and a slow (S), quick (Q) and normal (N) transition from night to day temperature, S and Q without and N with minimum ventilation, in the post-inoculation period (means of 40 plants).

Pre-inoculation climate night-day temperature in °C	Post-inoculation climate			
	S	Q	N	mean
12-23	65	65	51	60
16-23	54	52	53	53
20/12-23	58	53	53	55
20-23	50	47	42	46
24-23	49	42	33	41
16-17	51	43	51	48
16-20	60	57	53	57
16-23	54	52	53	53
16-26	56	51	44	50
mean	55	51	47	51

Table 6 - Percentages of internally rotten fruits by D. bryoniae in a spring crop of cucumbers with different pre- and post-inoculation climates (40 plants per treatment).

Pre-inoculation climate night-day temperature in °C	Post-inoculation climate			
	S	Q	N	mean
12-23	9.9	9.3	7.2	8.8
16-23	7.4	8.0	6.9	7.4
20/12-23	9.5	6.7	6.8	7.6
20-23	8.2	9.5	7.5	8.4
24-23	6.8	6.9	7.9	7.2
16-17	9.2	7.3	7.9	8.1
16-20	10.4	7.7	10.0	9.4
16-23	7.4	8.0	6.9	7.4
16-26	9.3	9.5	8.6	9.0
mean	8.9	8.1	7.8	8.2

Table 7 - Influence of climate regimes during the first two and the last three months on percentages leaf axils of the main stem diseased by Botrytis cinerea at the end of a spring crop of cucumbers (means of 40 plants).

Night-day temperature in °C in the first two months	Climate regime in the last three months			
	S	Q	N	mean
12-23	0.2	1.7	3.2	1.7
16-23	3.4	2.5	4.8	3.6
20/12-23	2.7	5.7	4.3	4.2
20-23	0.1	0.1	2.3	0.8
24-23	0.1	0.9	0.7	0.6
16-17	4.8	4.2	5.5	4.8
16-20	1.1	3.0	5.3	3.1
16-23	3.4	2.5	4.8	3.6
16-26	0.8	1.3	2.8	1.6
mean	1.7	2.4	3.6	2.6

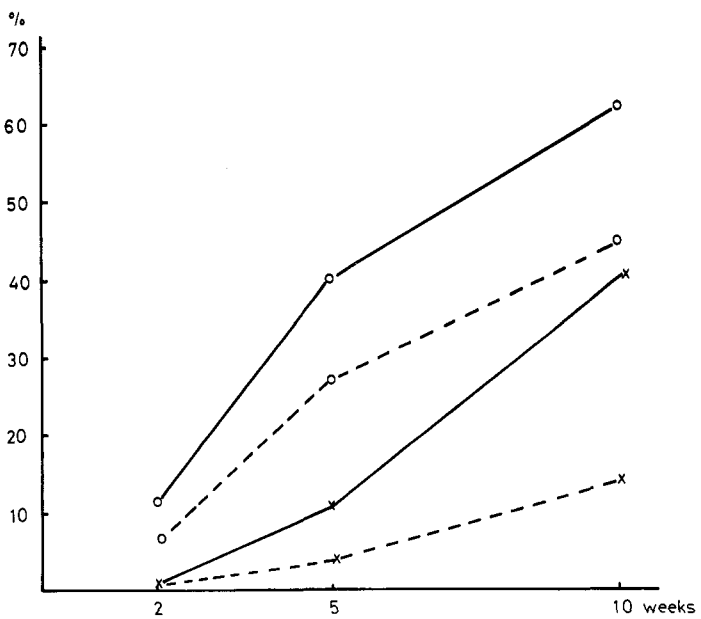

Figure 1

Effect of climate regimes on percentages of D. bryoniae diseased leaf axils of the main stem of uninoculated (x) and inoculated (o) plants of an autumn crop of cucumbers during 10 weeks after inoculation. Weak plants (——) were grown without and sturdy plants (---) with minimum ventilator and minimum heating settings.

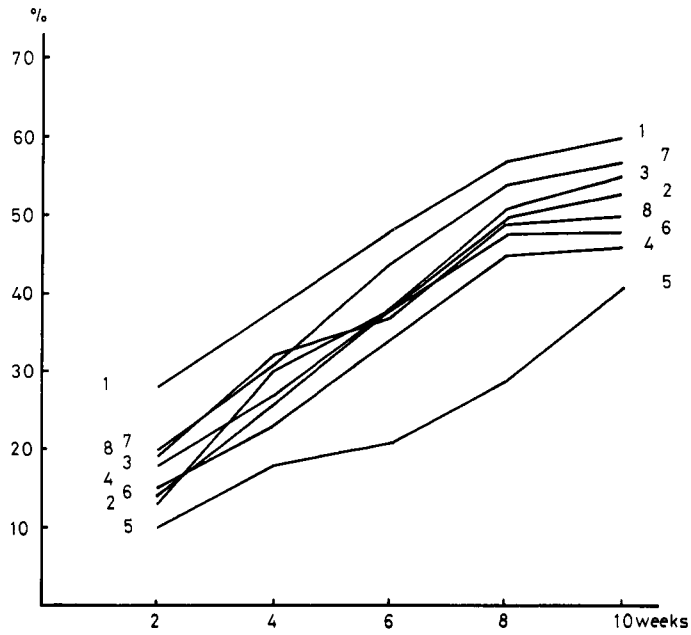

Figure 2

Influence of 8 temperature regimes in the pre-inoculation period on percentages leaf axils of the main stem with D. bryoniae lesions during 10 weeks after the first inoculation of a spring crop of cucumbers.
1 = 12/23, 2 = 16/23, 3 = 20-12/23, 4 = 20/23, 5 = 24/23, 6 = 16/17, 7 = 16/20, 8 = 16/26°C.

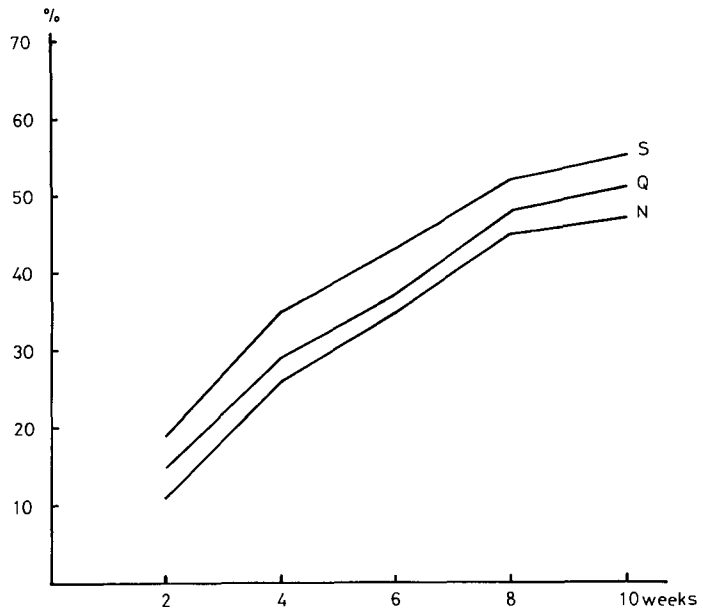

Figure 3

Influence of the post-inoculation climate on percentages leaf axils of the main stem with D. bryoniae lesions during 10 weeks after the first inoculation of a spring crop of cucumber.
S slow, Q quick and N normal transition form night to day temperature; S and Q without and N with minimum ventilation.

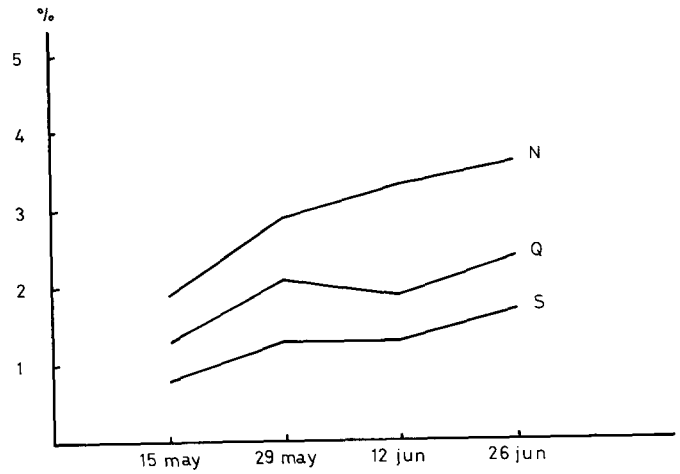

Figure 4

Influence of climate regimes during the last three months
of a spring crop of cucumbers on percentages leaf axils of
the main stem diseased by Botrytis cinerea.
S slow, Q quick and N normal transition from night to day temperature;
S and Q without and N with minimum ventilation.