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A pattern in the appearance of cucumber powdery mildew in Dutch glasshouses

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Abstract

An inquiry was held in 1982, 1983 and 1984 to collect information on the survival and dispersal of cucumber powdery mildew. Growers who planted a crop in December, January or February were asked when they observed mildew for the first time in their crop.

A gradual increase in the number of infected crops was observed from planting until May. The earliest observations of infected crops were immediately after planting. The weeks of the first observation of mildew, the disease-free periods and the apparent rates of increase of infected crops are presented for various districts. In the districts with the highest crop density (Pijnacker), mildew was generally observed early in the growing season, while the apparent rate of increase of infected crops was higher than in other districts. In the district with the lowest crop density (Northern Netherlands), mildew was observed late in the growing season and the apparent rate of increase of infected crops was low. Possible means of survival and dispersal of inoculum are discussed. It is suggested that overwintering of inoculum is possible because cucumber plants are grown all year round. Dispersal of cucumber powdery mildew is suggested to take place by transportation of infected planting stock, visitors and wind.

Additional keywords: Cucumis sativus, Sphaerotheca fuliginea, dispersal, survival.

Introduction

Cucumber powdery mildew is a serious disease in cucumber crops; it reduces the assimilating leaf area. The two most recorded species are *Erysiphe cichoracearum* DC. emend. Salm. and *Sphaerotheca fuliginea* (Schlecht.: Fr.) Poll. As perithecia are rare, the conidial characteristics are used to identify these two species (Boesewinkel, 1980). In the Netherlands, cucumber powdery mildew was identified as *S. fuliginea* in 1964 (Boerema and Van Kesteren, 1964), and this has been the only species since then. Cucumber powdery mildew is generally favoured by dry conditions, moderate temperatures and reduced light intensity, but it can develop under a wide range of climatic conditions (Sitterly, 1978). In the glasshouse, powdery mildew conidia are dispersed by air currents (Frinking and Scholte, 1983). On the sources of the primary inoculum and the exchange of inoculum between glasshouses little information is available.

Glasshouse-grown cucumbers are, after tomatoes, the second vegetable crop in Dutch horticulture. The total area in 1983 was 733 ha, with an export value of 312 million guilders (Centraal Bureau voor de Statistiek, Voorburg, 1983). The cucumber

cultivars, grown in soil or on artificial substrates, are 100% female, parthenocarpic and mildew-sensitive. The early production crops are planted in December, while the late crops are removed in November. Some growers have one crop from December/January until October. Others remove the crop in July/August and immediately plant a new one, which produces until November. Most growers buy 5-to-6-week-old cucumber plants from specialized nurseries. In order to provide the growers with plants in December, the nurseries have to sow cucumbers in October/November. Six to seven weeks after planting in the production glasshouses, the first cucumbers are harvested. In this way cucumbers are supplied throughout the year, except in December and January. Cucumber plants are continuously present, although on a variable area (Fig. 1).

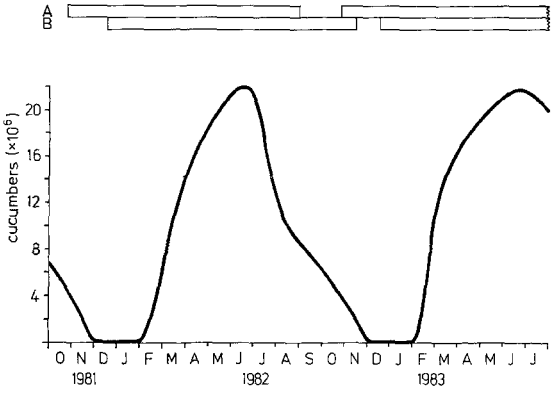

Fig. 1. Number of cucumbers ($\times 10^6$) supplied at thirteen auction markets and presence of cucumber plants in nurseries (A) and production glasshouses (B) throughout the year.

An inquiry was held in 1982, 1983 and 1984 to collect information on the survival and dispersal of cucumber powdery mildew.

Materials and methods

Telephone inquiry. Information was obtained by telephone from growers who plant their cucumber crops in December, January or February. Crops planted in March, April or May were not included in the inquiry. Addresses were kindly provided by the extension service, the auction market of Pijnacker and the chemical industries. All available addresses were used, except from Pijnacker where a random selection was made (Fig. 2).

The inquiry was held in May 1982, 1983 and 1984 (week numbers 19, 20 and 21). Information was asked about the week of cucumber planting and the week of first observation of cucumber powdery mildew. To prevent negative week numbers, the first week in January was given number 5 (in 1982 and 1983) or 6 (in 1984). When at the time of the inquiry the cucumber crop was mildew-free, the hypothetical week number 35 was used for statistical purposes. Week number 35 was chosen because experience learned that by that time all growers had observed cucumber powdery mildew.

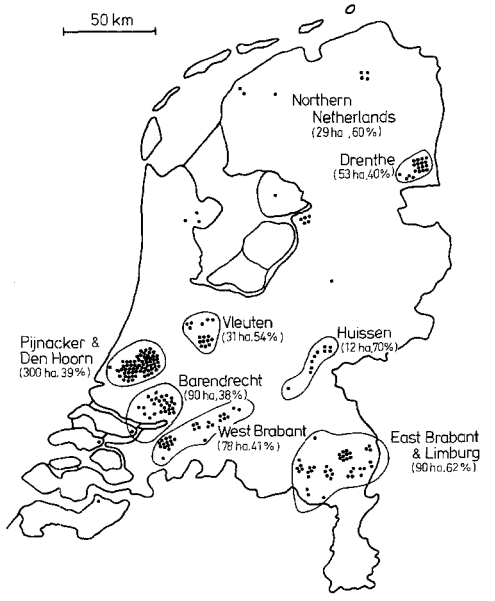

Fig. 2. Geographical distribution in the Netherlands of cucumber glasshouses selected for the inquiry. Tthe data between brackets refer to (1): total area including crops planted in December, January and February (78%) and crops planted in March, April and May (22%), and (2): estimated area selected for the inquiry as a percentage of the area planted in December, January and February (Centraal Bureau voor de Statistiek, 1983).

In this figure Pijnacker and Den Hoorn are presented as one district because no data were available on the area of cucumber crops in the separate districts.

Statistics. A student t-test was used to detect differences between the mean week numbers of the first observation of mildew (FOM, Table 1) and the means of disease-free periods (DFP, Table 2) for each district (Beyer, 1976). Differences in the distribution of FOM and DFP values were compared between 1982, 1983 and 1984, using the Kolgomorov-Smirnov test. The apparent rates of increase of infected crops (AIC, Table 3) were determined as described by Van der Plank (1963).

Results

Week of first observation of mildew. (FOM, Table 1, Figs 3 and 4).

1982. The earliest observation of mildew was in December, 1981. In the districts of Pijnacker and Den Hoorn the mean values of FOM were both 16 (medio March), which was earlier than in the other districts. In the districts of Huissen and Northern Netherlands the mean values of FOM were 32 and 28, respectively, which was later than in the other districts.

1983. The earliest observation of mildew was in January, 1983. In most districts the mean values of FOM were between 21 and 26 (April, May). In the districts of Drenthe and Northern Netherlands the mean values of FOM were 31, which was later than in the other districts.

1984. The earliest observation of mildew was in week 6 (January). In the district of Pijnacker the mean value of FOM was lowest, viz. 21 (medio April). In the other districts the mean values of FOM varied from 25 to 32.

Comparison 1982, 1983, 1984. In 1983 the mean values of FOM in the districts of Pijnacker and Den Hoorn were 5 and 8 weeks higher than in 1982. In 1984 FOM values in most districts were similar to those in 1983, except for the districts of Vleuten and East Brabant and Limburg, where mildew was observed later. In 1984 mildew was observed later than in 1982 in six districts. Only in the districts of Huissen, Drenthe and Northern Netherlands FOM values of 1984 were not higher than in 1982.

Table 1. Mean week numbers[1] of cucumber planting and of first observation of mildew in various districts in the Netherlands in 1982, 1983 and 1984.

District	Number of crops			Cucumber planting			First observation of mildew (FOM)		
	1982	1983	1984	1982	1983	1984	1982	1983	1984
Pijnacker	35	61	73	5	6	6	16 ab[2]	21 a x[3]	21 a x
Den Hoorn	37	31	28	5	6	6	16 a	24 ab x	26 bc x
Barendrecht	30	27	27	6	6	6	20 bc	24 ab	28 bcd x
Huissen	10	7	7	9	11	10	32 f	24 abcd	32 cd
Vleuten	15	13	12	7	7	7	22 cd	25 ab	30 bcd xxx
East Brabant and Limburg	46	43	41	8	7	7	24 de	23 ab x	26 b xx
West Brabant	28	25	25	8	7	7	22 cd	26 b d	29 bcd x
Drenthe	18	17	17	7	7	6	24 cde	31 c	25 ab
Northern Netherlands	17	14	12	9	9	9	28 ef	31 cd	32 d
Total	236	238	242	7	7	7	23	25 x	28 xxx

[1] First week of January is given number 5 (1982, 1983) or 6 (1984).

[2] Values in columns followed by the same letter are not significantly different (Student test, p = 0.05).

[3] x: distribution of values is significantly different from that in 1982, xx: distribution of values is significantly different from that in 1983, xxx: distribution of values is significantly different from those in both 1982 and 1983 (Kolgomorov-Smirnov test, p = 0.05).

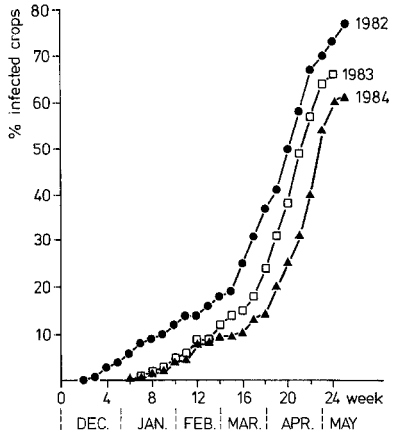

Fig. 3. Disease progress of cucumber powdery mildew in 1982, 1983 and 1984 in cucumber crops in the Netherlands.

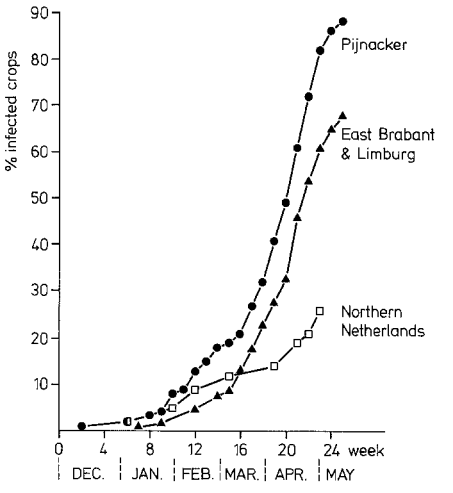

Fig. 4. Disease progress curves of cucumber powdery mildew in the districts of Pijnacker, East Brabant & Limburg and Northern Netherlands in 1982, 1983 and 1984. The points represent mean values of data obtained in 1982, 1983 and 1984.

Disease-free period (DFP, Table 2). The disease-free period is defined as the period in weeks from planting until the observation of the first mildew symptoms.

1982. In six crops the earliest observation of mildew was immediately after planting. In the districts of Pijnacker and Den Hoorn the mean values of DFP were 12 and 10, respectively, which was shorter than in the other districts. In the districts of Huissen and Northern Netherlands the mean DFP values were higher than in the other districts, viz. 23 and 19, respectively.

1983. In one crop mildew was observed immediately after planting. For most districts the mean DFP values were between 14 and 19. In the districts of Drenthe and Northern Netherlands the mean DFP values were 24 and 22, respectively, which was higher than in the other districts.

1984. In two crops, mildew was observed immediately after planting. The lowest mean DFP value was recorded for the district of Pijnacker, viz. 16. The mean DFP values of the other districts, ranging from 18 to 24, did not differ significantly.

Comparison 1982, 1983, 1984. In 1983 the mean DFP values of Pijnacker, Den Hoorn and Drenthe were higher than in 1982. In 1984 the districts of Barendrecht and East Brabant and Limburg had higher mean DFP values than in 1983. In 1984 the DFP was longer than in 1982 for six districts. Only in the districts of Huissen, Drenthe and Northern Netherlands DFP values were similar to those in 1982.

Apparent rate of increase of infected crops (AIC, Table 3). The AIC is estimated according to Van der Plank (1963).

1982. The AIC value was lowest for the district of Northern Netherlands (0.11), and highest for the district of Pijnacker (0.31). The AIC values for the other districts varied from 0.20 to 0.25.

Table 2. Mean disease-free period (DFP) in weeks in various districts in the Netherlands in 1982, 1983 and 1984.

District	Disease-free period[1]		
	1982	1983	1984
Pijnacker	12 ab[2]	15 a x[3]	16 a x
Den Hoorn	10 a	18 abc x	21 bc x
Barendrecht	14 c	18 abc	22 bc xxx
Huissen	23 e	14 ab	22 bc
Vleuten	14 bc	18 abc	24 c x
East Brabant and Limburg	17 cd	16 ab	19 b xxx
West Brabant	15 bc	19 bc	22 bc x
Drenthe	16 cd	24 d x	18 ab
Northern Netherlands	19 de	22 cd	24 bc
Total	16	18 x	21 xxx

[1] Disease-free period: period in weeks from planting until observation first cucumber powdery mildew.
[2] Values in columns followed by the same letter are not significantly different (p = 0.05).
[3] x: distribution of values is significantly different from that in 1982, xx: distribution of values is significantly different from that in 1983, xxx: distribution of values is significantly different from those in both 1982 and 1983 (Kolgomorov-Smirnov test, p = 0.05).

Table 3. Apparent rate of increase (AIC) of crops infected with cucumber powdery mildew in various districts in the Netherlands in 1982, 1983 and 1984.

District	Apparent rate of increase[1]		
	1982	1983	1984
Pijnacker	0.31	0.28	0.31
Den Hoorn	0.25	0.21	0.16
Barendrecht	0.20	0.24	0.24
Vleuten	0.22	—[2]	—
East Brabant and Limburg	0.24	0.40	0.23
West Brabant	0.23	0.23	—
Drenthe	0.20	0.36	0.21
Northern Netherlands	0.11	0.12	0.07
Total	0.22	0.29	0.26

[1] Linear regression coefficient after logit transformation.
[2] Insufficient data available.

1983. The AIC value for the district of Northern Netherlands was low again, viz. 0.12. The highest AIC value was recorded for the district of East Brabant and Limburg (0.40).

1984. The district Northern Netherlands showed the lowest AIC value (0.07), the district of Pijnacker the highest (0.31).

Comparison 1982, 1983, 1984. AIC values of the district of Pijnacker were constantly high, those of the district of Northern Netherlands were constantly low. Values of the other districts varied between those extremes.

Discussion

Although data obtained by telephone will certainly contain inaccuracies, the good coverage of the inquiry and the intensity with which the growers attend to their crop, guarantee a representative picture of the pattern of appearance of cucumber powdery mildew in the Netherlands.

Survival of conidia is an important factor in the epidemiology of cucumber powdery mildew, particularly because any glasshouse is empty for almost two months. In general, powdery mildew conidia can survive for a period of up to 40 days without a host plant (Blumer, 1967), a period too short to span the gap between two cucumber growing seasons. Perithecia can survive for a longer time. Since perithecia have not yet been found in the Netherlands, their role in the epidemiology of cucumber powdery mildew seems negligible. If conidia surviving the crop-free period in a glasshouse served as the inoculum in that same glasshouse, the symptoms should appear within 14 days after planting. Lesions were only occasionally observed so soon after planting. Even in glasshouses with a heavily diseased crop in the previous year, the new crop can remain mildew-free for months. It is concluded that conidia surviving in a crop-free glasshouse are probably not the primary inoculum.

Since *S. fuliginea* is recorded on many plant species, conidia could possibly survive on plants other than Cucurbitaceae. However, within *S. fuliginea* different pathotypes exist that differ in their ability to attack particular host species (Abiko, 1978, 1982a, 1982b; Boesewinkel, 1979). Thus, infection of cucumber plants with powdery mildew conidia from other plant species seems improbable, although it was suggested to occur in England (Stone, 1962) and Israel (Dinoor, 1974). Moreover, in the Netherlands *S. fuliginea* appears on cucumbers in December/January, when low temperatures outside the glasshouse almost exclude infection from sporulating lesions on non-Cucurbitaceae. The statement that, from a crop-oriented viewpoint, the role of wild hosts in plant disease epidemiology is a minor one, seems appropriate for cucumber powdery mildew (Wheeler, 1981).

If we assume that conidia cannot survive crop-free periods and that cucumber plants can only be infected by a specific form of *S. fuliginea,* then cucumber powdery mildew inoculum can only originate from infected Cucurbitaceae. In the Netherlands, Cucurbitaceae do not occur outside the glasshouse in the winter months. Although the growing season for cucumbers is discontinuous in individual glasshouses, in the Netherlands as a whole cucumber plants are grown year-round (Fig. 1). Especially in the districts of Pijnacker and Den Hoorn, with a high density of production crops and nurseries, cucumber plants are always available for the mildew to grow on. Few conidia will make the step from the old crops to young plants in November/December.

However, the fact that young cucumber plants cannot be adequately treated with fungicides because of phytotoxicity, enables these few conidia to establish infections. Since only few conidia will be able to infect plants in nurseries, much between-glasshouse dispersal will have to take place in order to reach the high level of incidence observed in July and August. The first mechanism of dispersal is by means of planting stock, carrying latent infections, that is transported from nurseries to production glasshouses. Especially when cucumber plants show mildew symptoms immediately or a few weeks after planting, growers impute this phenomenon to infected planting stock. The intensity of this mechanism varies from year to year, possibly influenced by weather, hygienic measures, disease pressure and planting dates.

In districts with a high crop density, such as Pijnacker and Den Hoorn, the probability of infection of young plants will be higher than in other districts. The relatively high occurrence of early infected crops in 1982 in those districts may be attributed to that high crop density.

A second possible mechanism of dispersal is the transportation of conidia from one crop to another by persons visiting glasshouses. The observation of growers, who detected the first mildew symptoms on places where visitors entered the crop, appears to affirm this possibility.

Other parts of the glasshouse where first mildew symptoms were frequently observed, were places with much air circulation. Since glasshouses are not so air-tight as has often been suggested, conidia can probably leave and enter the glasshouses fairly easily, as has been reported for other pathogens (Frinking and Scholte, 1983; Zadoks, 1967; Zandvoort, 1968). The occurrence of first mildew lesions on places with much air circulation was not restricted to districts with a high crop density, but was also observed in districts where crops were situated several kilometers apart. These observations suggest a third mechanism of dispersal, namely the dispersal of conidia by wind.

Significant differences in FOM and DFP values were observed between years. Probably these differences were not caused by one factor only, but by an inextricable complex of factors such as weather, hygienic measures, planting dates, disease pressure and chemical control. In spite of this complexity a pattern can be indicated.

1. In all districts a gradual increase in numbers of infected crops was observed from planting until May in 1982, 1983 and 1984.
2. Mildew was generally observed earlier in districts with a high crop density than in districts with a low crop density.
3. The mean disease-free period was shorter in districts with a high crop density, and longer in districts with a low crop density.
4. The apparent rate of increase of infected crops in the district of Northern Netherlands was lower than in the other districts, whereas the AIC in the district of Pijnacker was always high.

A few general conclusions are ventured. Overwintering of inoculum is possible because cucumber plants are grown all year round. Dispersal of cucumber powdery mildew early in the growing season takes place by transportation of infected planting stock and by visitors. When the disease pressure increases in the course of the growing season, inoculum is dispersed by wind.

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Samenvatting

Een patroon in het verschijnen van komkommermeeldauw in Nederlandse kassen

In 1982, 1983 en 1984 werd een enquête gehouden om informatie te verzamelen over de overleving en verspreiding van komkommermeeldauw. Tuinders die hun gewas geplant hadden in december, januari of februari werd gevraagd wanneer ze de eerste meeldauw hadden waargenomen.

Een geleidelijke toename van het aantal geïnfecteerde gewassen werd waargenomen vanaf het planten tot aan mei. Geïnfecteerde gewassen werden voor het eerst waargenomen direct na het planten. De weeknummers van de eerste meeldauwwaarnemingen, de ziekte-vrije perioden en de snelheden waarmee het aantal geïnfecteerde gewassen toenam, werden berekend voor verschillende districten.

In het district met de grootste gewasdichtheid (Pijnacker) werd de meeldauw over het algemeen vroeg in het groeiseizoen waargenomen, terwijl de snelheid waarmee het aantal geïnfecteerde gewassen toenam hoger was dan in andere districten. In het district met de laagste gewasdichtheid (Noord Nederland) werd de meeldauw laat in het seizoen waargenomen en was de snelheid waarmee het aantal geïnfecteerde gewassen toenam laag.

Mogelijke manieren van overleving en verspreiding van inoculum worden besproken. Er wordt gesuggereerd dat het overwinteren van inoculum mogelijk is, doordat komkommerplanten het gehele jaar aanwezig zijn. De verspreiding van komkommermeeldauw zou plaats kunnen vinden door het vervoer van geïnfecteerd plantmateriaal, bezoekers en wind.

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