Neth. J. Pl. Path. 91 (1985) 225-233

Influence of time of transition from night to day temperature regimes on incidence of Didymella bryoniae and influence of the disease on growth and yield of glasshouse cucumbers

N.A.M. VAN STEEKELENBURG

Research Institute for Plant Protection (IPO), P.O. Box 9060, 6700 GW Wageningen, the Netherlands*

Accepted 14 March 1985

Abstract

The influence of transition from night to day temperature 3 h before, 1 h before, 1 h after and 3 h after sunrise on the incidence of *Didymella bryoniae* was studied both on inoculated and on uninoculated glasshouse-grown cucumber plants. The effect of inoculation on plant growth and fruit production was studied as well.

The later the transition to day temperature took place, the longer were the periods with a high relative air humidity and of condensation of water on fruits.

The time of transition had no effect on plant growth, yield, disease incidence on growing tips, number of lesions on the main stems of uninoculated plants and external fruit rot. The later the transition to day temperature took place, the more lesions on the main stem of inoculated plants appeared and the higher was the incidence of internal fruit rot.

Inoculation of plants increased the number of lesions on the main stem, the disease incidence on growing tips, the production of misshapen fruits and the internal and external fruit rot. The number of secondary side shoots was increased but the total number of their internodes was reduced by inoculation.

Inoculation caused an 18% reduction in number of internodes over a period of four weeks and a 10% reduction in number of fruits in the corresponding harvest period.

The consequences of a more humid glasshouse climate and of a high infection pressure of *D. bryoniae* for the grower are briefly discussed.

Additional keywords: Cucumis sativus, glasshouse climate, *Mycosphaerella citrullina, Mycosphaerella melonis,* stem and fruit rot.

Introduction

*Didymella bryoniae (*Auersw.) Rehm (synonyms: *Mycosphaerella citrullina* (C.O. Sm.) Gross. and *Mycosphaerella melonis* (Pass.) Chiu and Walker) causes stem and fruit rot in cucumber crops. Symptoms and economic importance of the disease have been described earlier (Van Steekelenburg, 1978, 1982; Van Steekelenburg and Van de Vooren, 1981). Under controlled environmental conditions, infection of cucumber leaf tissue occurred only if the surface was kept wetted and for further expansion of the

* Seconded to the Glasshouse Crops Research and Experiment Station, Zuidweg 38, 2671 MN Naaldwijk, the Netherlands.

disease high humidity was required (Svedelius and Unestam, 1978).

In glasshouse crops, the incidence of the disease is directly and indirectly influenced by the glasshouse climate (Van Steekelenburg, 1984; Van Steekelenburg and Van de Vooren, 1981). The glasshouse climate is determined by a number of factors, of which outdoor climate, heating, ventilation and transpiration of the plants are the most important ones. After sunrise plant transpiration and, consequently, humidity increase. Moreover, plant and fruit temperatures rise slower than the air temperature. This results in water condensation on plant parts, especially fruits, with a temperature below dew point (Mihara and Hayashi, 1978). In glasshouse crops a low night temperature is maintained to save energy. However, in combination with a great interval between night and day temperature, it will increase humidity and condensation on fruits. In heated glasshouse crops the air temperature and, consequently, the plant temperature can be raised before the air temperature is heated up through sun heat. When the day setpoint is reached ventilation will decrease the air humidity. Therefore, the effect of time of transition from night to day conditions on the glasshouse climate and, consequently, on the incidence of stem and fruit rot was studied.

In previous experiments it was observed that *D. bryoniae* can reduce the production of fruits (Van Steekelenburg, 1983, 1984; Van Steekelenburg and Van de Vooren, 1981). The influence of the incidence of *D. bryoniae* on fruit production and plant growth is reported in this paper as well.

Materials and methods

Climate regimes. The experiment was conducted under computer-controlled climate conditions in eight compartments of the glasshouse described by Van de Vooren and Koppe (1975). Equal climate regimes were set in all compartments during the first five weeks until the growing tip of the main stem was removed. Subsequently the time of transition from night to day temperature was set in two replicates 3 h before, 1 h before, 1 h after and 3 h after sunrise. The period of transition was 2 h. The heating temperatures were 16/24 °C (night/day) and ventilation temperatures were 17/26 °C (night/day).

Transition from day to night conditions was equal for all treatments: over a period of 2 h, starting 2 h before sunset. Temperatures were measured with copper constantan thermo-couples. Humidity was calculated from dry and wet bulb measurements.

Plants. Five-week-old cucumber plants of cv. Profito, resistant to powdery mildew, were planted in six rows of ten plants in each compartment on 21 April 1982. The plants had been grafted on *Cucurbita ficifolia.* The side shoots were removed along the main stem until the plants reached the suspending wire at about 2.1 m above soil level. Then the growing tip of the main stem was removed and two side shoots were allowed to grow down from the top. At about 0.8 m above soil level the growing tips of the side shoots were removed and secondary side shoots were allowed to develop.

Pathogen and inoculation. Virulent isolates of *D. bryoniae* were grown for two weeks on oat meal agar under black light (Philips TL 20 W F20 T12 BLB). The conidia were washed off with water. All plants of two neighbouring rows were sprayed with 0.3 l suspension each (10^6 conidia per ml) in the beginning of June, when three to four leaves on the side shoots had developed. Inoculation was repeated one month afterwards.

Plant growth measurements. The number of internodes on side shoots and secondary side shoots and the number of secondary side shoots were counted at weekly or fortnightly intervals on two rows of plants in each compartment. Plant growth was recorded during a period of seven weeks after the first inoculation.

Fruit production measurements. Twice a week, fruits were harvested, counted and weighed, after grading in full-grown and misshapen fruits.

Disease assesment. The number of lesions on the main stem was counted several times. The disease incidence on the growing tip and youngest leaves was rated according to an arbitrary scale from 0 to 4, in which 0 = no symptoms, 1 = small yellow lesions in the youngest leaves, 2 = slight malformation of leaves, 3 = severe malformation of leaves and 4 = growing tip (nearly) dead. At harvest, suspect fruits were cut longitudinally at the blossom end to check for internal rot. The fruits were also checked for external rot caused by *D. bryoniae.*

Results

Glasshouse climate

The temperature and humidity were only different for the four regimes during the morning hours between 3 h before sunrise and about 4 h after sunrise. The later the transition to day conditions took place, the longer the period a high relative humidity was maintained (Fig. 1). It was observed that in the early morning hours fruits were often wet from condensation in all treatments. The earlier the transition to day conditions, the earlier the fruits dried up. In the treatments with transition after sunrise the period the fruits remained wet was about two hours longer than with transition before sunrise.

Influence of climate on disease

Disease incidence on the main stem. No spontaneous infection was observed at the time of the first inoculation. Data on the development of the disease on the main stem are presented in Table 1. Disease incidence on inoculated plants was always more severe than that on uninoculated plants ($p < 0.01$). The climate regimes had no significant effect on the incidence of the disease on uninoculated plants. Transition to day conditions after sunrise increased the number of *D. bryoniae* lesions on inoculated plants after four weeks. Later in the season the differences in disease incidence decreased.

Disease incidence on the growing tip. Three weeks after inoculation the disease incidence on growing tips of side shoots was only slight with no significant differences for the different climate regimes. Uninoculated plants did not show symptoms at all. The climate regimes had no effect either on the disease incidence on growing tips of secondary side shoots. The mean disease index of the secondary side shoots increased from 0.04 to 0.45 on uninoculated plants and from 0.41 to 1.03 on inoculated plants during the period between 4 and 7 weeks after the first inoculation.

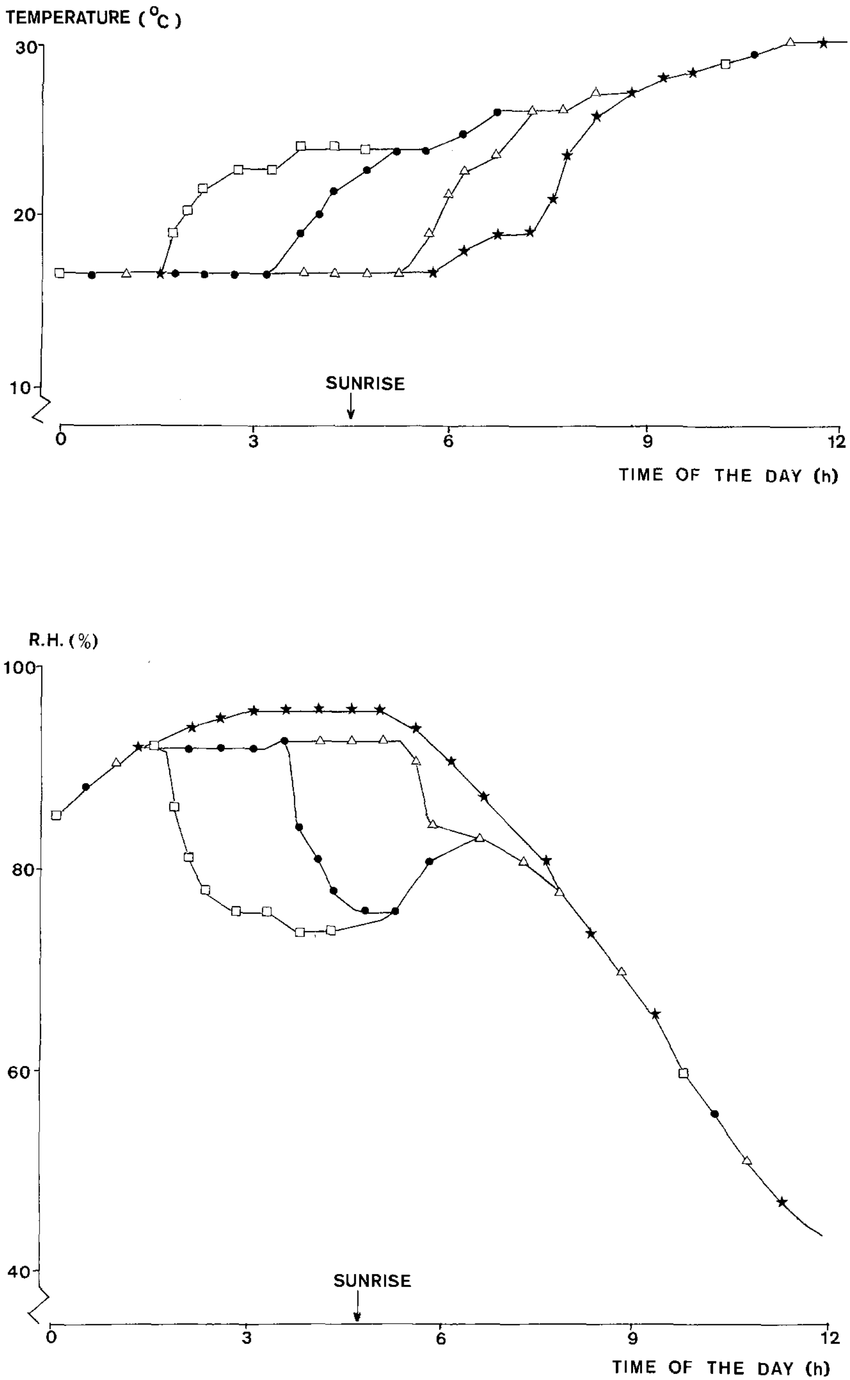

Fig. 1. Temperature and relative humidity of the glasshouse air in a cucumber crop with transition to day conditions 3 h before (□), 1 h before (●), 1 h after (△) and 3 h after (★) sunrise in the morning of 10 June.

Table 1. Number of lesions caused by *D. bryoniae* on the main stem of uninoculated (U) and inoculated (I) cucumber plants grown at different times of transition to day conditions. Treatments included 20 plants in each of two replicates.

Transition time to sunrise	30 June		5 August		22 September	
	U	I	U	I	U	I
−3 h	0.3[a1]	1.8[a]	2.6[a]	5.5[a]	6.5[a]	9.2[a]
−1 h	0.3[a]	3.4[a]	3.5[a]	6.2[a]	5.6[a]	9.7[a]
+1 h	0.9[a]	6.3[b]	3.4[a]	7.9[a]	5.9[a]	9.3[a]
+3 h	0.5[a]	7.3[b]	3.9[a]	8.4[a]	5.9[a]	9.0[a]

[1] Entries of one column marked with different letters differ significantly at $p < 0.05$ (Student test).

Internal fruit rot. The first fruits with internal rot were found on 17 June, 15 days after the first inoculation. The percentage of fruits with internal rot was higher on inoculated plants than on uninoculated ones in the harvest period until 12 July (Table 2). No effect of inoculation was observed later in the season, however, over the whole period until 20 September there was still some effect. The climate regimes had a significant effect ($p < 0.05$) on the incidence of internal rot (Fig. 2). The later the transition to day conditions took place, the higher was the number of fruits with internal rot. The average percentage of fruits with internal rot of inoculated and uninoculated plants for the regimes with transitions to day conditions 3 h before, 1 h before, 1 h after, 3 h after sunrise were 2.1, 4.1, 6.4 and 6.8, respectively.

Table 2. Effect of inoculation of cucumber plants with *D. bryoniae* on total fruit production and on percentage of fruits with internal and external rot in two harvest periods. Treatments included 20 plants in each of eight replicates.

Harvest period	Inoculation	Fruit production		Internal fruit rot (%)	External fruit rot (%)
		kg per plant	number per plant		
14 June - 12 July	−	4.2[a1]	7.5[a]	2.6[c]	0.9[a]
	+	3.6[b]	6.7[b]	4.5[d]	5.2[b]
14 June - 20 Sept.	−	15.1[a]	29.8[c]	4.4[e]	1.3[a]
	+	13.9[b]	28.0[d]	5.6[f]	4.0[b]

[1] Entries of one harvest period in one column marked with a and b differ significantly at $p < 0.01$; marked with c and d at $p < 0.05$; marked with e and f at $p = 0.06$ (analysis of variance).

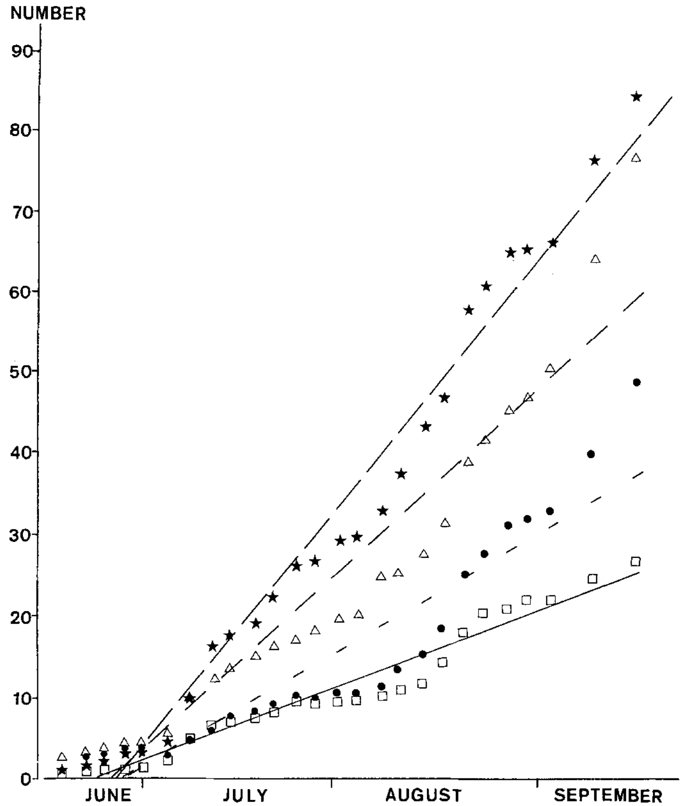

Fig. 2. Development of the total number of fruits with internal rot per 40 plants, 20 plants being uninoculated and 20 plants inoculated with D. bryoniae, in a glasshouse cucumber crop with transition to day conditions 3 h before (□), 1 h before (●), 1 h after (△) and 3 h after (★) sunrise (means of two replicates).

External fruit rot. Only inoculation had a significant effect on the occurrence of external fruit rot. The percentage of fruits with external rot from inoculated plants was three times higher than that from uninoculated plants (Table 2).

Influence of the disease on growth and yield

Plant growth. The difference in climate regime had no significant effect on the total number of internodes, neither on side shoots, nor on secondary side shoots. Inoculation had no effect either on the number of internodes on the side shoots. On the secondary side shoots, inoculation reduced the total number of internodes per plant with 18 to 15%, depending on the growing period, whilst the number of secondary side shoots had increased compared with uninoculated plants (Table 3). The data of 30 June are the result of the first inoculation and the data of 23 July of both the first and the second inoculation.

Table 3. Effect of inoculation of cucumber plants with *D. bryoniae* on the total number of internodes and on the number of secondary side shoots per plant. Treatments included ten plants in each of eight replicates.

Inoculation	Number of internodes		Number of secondary side shoots	
	30 June	23 July	30 June	23 July
–	26.4[a1]	79.1[a]	7.4[a]	11.6[a]
+	21.7[b]	67.3[b]	9.5[b]	12.8[a]

[1] Entries of one column marked with different letters differ significantly at $p < 0.05$ (analysis of variance).

Fruit production. Fruit production on the main stem was not influenced by climate regimes or inoculation. Therefore, only fruits from the side shoots and secondary side shoots were taken into account. The differences in climate regime had no significant effect on the total number and weight of the harvested fruits. Inoculation reduced the weight of the fruits with 13.5 to 7.9 %, depending on the duration of the harvest period (Table 2). As it takes 10 tot 14 days from flowering to harvest, the production until 12 July was influenced only by the first inoculation. The misshapen fruits are included in the total fruit production. Inoculation increased the production of misshapen fruits significantly ($p < 0.05$) from 0.94 to 1.11 kg per plant (18%).

Discussion and conclusions

With an early transition to day temperature the air humidity decreased as a result of the higher temperature (Fig. 1) and of the earlier opening of the ventilator windows. With a decreased air humidity the water on plant parts evaporated earlier. As a consequence environmental conditions for infection and expansion of the disease were less favourable. The incidence of stem and fruit rot was reduced substantially by heating up the glasshouse to the day setpoint before sunrise. The greater the interval between night and day temperature, the more important the early heating of the glasshouse will be as with lower temperatures a higher humidity will prevail.

An earlier transition to day temperature resulted in fewer lesions of *D. bryoniae* on the main stem only under circumstances of a high infection pressure after inoculation (Table 1). No difference in disease incidence was observed on growing tips. Apparently the microclimate on the growing tips and to a lesser extent on the main stem differed not very much for the four climate regimes. The most pronounced effect of the climate regime was on internal fruit rot (Fig. 2). It is most likely an indirect effect. Under more humid conditions and after condensation of water on diseased plant parts the release of ascospores of *D. bryoniae* will be enhanced (Fletcher and Preece, 1966; Schenck, 1968; Van Steekelenburg, 1983). This will result in an increased chance of flower infection, and flower infection is necessary to get internal fruit rot (unpublished data).

The climate regimes had no effect on the occurrence of external fruit rot. Wounding but not humidity is the most important factor in inciting external fruit rot (Van Steekelenburg, 1982).

Inoculation of plants increased infection pressure and, consequently, disease incidence on the main stem (Table 1), the growing tips and fruits (Table 2). Moreover, a higher infection pressure caused a reduction in fruit production (Table 2) and an increase in the incidence of misshapen fruits.

Inoculation caused a reduction of 4.7 internodes per plant (18 %) over a period of four weeks (Table 3) and a reduction of 0.8 fruits per plant (10 %) in the corresponding harvest period (Table 2). Every internode has a leaf axil with the initials of at least one fruit. Part of the young fruits abort spontaneously (De Lint and Heij, 1982). Although no effect of *D. bryoniae* on fruit abortion was observed in preliminary experiments it cannot be totally excluded that the disease increases abortion. With a high infection pressure of *D. bryoniae* there is not only the qualitative aspect of the rotten fruits, but also the invisible quantitative aspect of yield reduction may be important.

Acknowledgements

Thanks are due to Mrs B.C. van Dam for her help in carrying out the experiments, to J.C. Bakker for his care of the climate regimes, to J.C.M. Withagen for statistical analysis and to W.A. van Winden for his help with the English text.

Samenvatting

Invloed van het tijdstip van overgang van de nacht- naar de dagtemperatuur op het optreden van Didymella bryoniae en de invloed van de ziekte op groei en produktie van kaskomkommers

De invloed van het 3 uur vóór, 1 uur vóór, 1 uur na en 3 uur na zonsopgang overgaan van de nacht- naar de dagtemperatuur op het optreden van *Didymella bryoniae* werd zowel op geïnoculeerde als op niet-geïnoculeerde planten van kaskomkommers onderzocht. De invloed van inoculatie op de groei van de planten en de produktie van vruchten werd eveneens nagegaan.

Hoe later naar de dagtemperatuur werd overgegaan, hoe langer de perioden met een hoge relatieve luchtvochtigheid waren en hoe langer de perioden waarin condensatie van water op vruchten optrad.

Het tijdstip van overgang had geen effect op de groei van de planten, de opbrengst, de aantasting van groeipunten, het aantal lesies op de hoofdstengel van niet geïnoculeerde planten en uitwendig vruchtrot. Hoe later naar de dagtemperatuur werd overgegaan, hoe meer lesies na vier weken op de hoofdstengel van geïnoculeerde planten en hoe meer vruchten met inwendig rot voorkwamen.

Door inoculatie van de planten nam het aantal lesies op de hoofdstengel, de aantasting van groeipunten, de produktie van stekvruchten en het aantal vruchten met in- en uitwendig rot toe. Het aantal zijscheuten van de tweede orde nam toe, maar het totaal aantal internodiën ervan nam door inoculatie af. Inoculatie reduceerde het aantal internodiën met 18% over een periode van vier weken en die van het aantal vruchten met 10% in de overeenkomstige oogstperiode. De praktische consequenties van een

vochtig kasklimaat en van een hoge infectiedruk van *D. bryoniae* worden kort aangegeven.

References

Fletcher, J.T. & Preece, T.F., 1966. *Mycosphaerella* stem rot of cucumbers in the Lea Valley. Ann. appl. Biol. 58: 423-430.

Lint, P.J.A.L. de & Heij, G., 1982. Night temperature and flower abortion of glasshouse cucumber (*Cucumis sativus* L.). Neth. J. agric. Sci. 30: 331-339.

Mihara, Y. & Hayashi, M., 1978. Latent heat of water for cooling and dehumidifying ventilation in greenhouses. Acta Hort. 87: 329-336.

Schenck, N.C., 1968. Incidence of airborne fungus spores over watermelon fields in Florida. Phytopathology 58: 91-94.

Steekelenburg, N.A.M. van, 1978. Chemical control of *Didymella bryoniae* in cucumbers. Neth. J. Pl. Path. 84: 27-34.

Steekelenburg, N.A.M. van, 1982. Factors influencing external rot of cucumber caused by *Didymella bryoniae*. Neth. J. Pl. Path. 88: 47-56.

Steekelenburg, N.A.M. van, 1983. Epidemiological aspects of *Didymella bryoniae*, the cause of stem and fruit rot of cucumber. Neth. J. Pl. Path. 89: 75-86.

Steekelenburg, N.A.M. van, 1984. Influence of ventilation temperature and low ventilation rates on incidence of *Didymella bryoniae* in glasshouse cucumbers. Acta Hort. 156 (in press).

Steekelenburg, N.A.M. van & Vooren, J. van de, 1981. 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*. Acta Hort. 118: 45-65.

Svedelius, G. & Unestam, T., 1978. Experimental factors favouring infection of attached cucumber leaves by *Didymella bryoniae*. Trans. Br. mycol. Soc. 71: 89-97.

Vooren, J. van de & Koppe, R., 1975. The climate glasshouse at Naaldwijk. Neth. J. agr. Sci. 23: 238-247.