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The relationship between the Aphis gossypii Glover group and cucumber mosaic virus in autumn cucumbers*

Wa. M. Th. J. de Brouwer and H. J. M. van Dorst

Glasshouse Crops Research and Experiment Station, Naaldwijk, the Netherlands

Summary

The wide-spread damage caused by cucumber mosaic virus (CMV) to autumn cucumbers in 1963, led to an investigation into aphids which are the vectors of this virus. In the South Holland glasshouse district *Aphis gossypii* Glover is the only aphid occurring as a pest of glasshouse cucumbers. Yellow water traps were set up in various places. There appeared to be no relationship between the extent of the cucumber crop in an area and the number of *A. gossypii* caught in the traps. The peak month for flight of these aphids is August. More aphids were caught in the yellow traps outside the glasshouse than in the traps placed inside the glasshouse beneath the ventilators. However, percentage-wise a larger proportion of the aphids caught in the traps inside the glasshouses belonged to the *A. gossypii* group than was the case in the outside traps, and more of these aphids were caught in cucumber houses than in tomato houses.

A. gossypii rapidly colonized cucumber and gherkin plants placed outside and under frame lights for 24 hours. *A. gossypii* plays an important part in the infection of CMV which occurred most frequently in August. However, only a small percentage of the aphids was responsible for transmission of the virus.

Introduction

Although cucumbers are grown in glasshouses the whole year round, cucumber mosaic virus (CMV, Cucumis virus 1) causes damage virtually only to the autumn crop. In 1963, the virus caused so much damage that it was considered necessary to carry out research into the vectors of the virus, aphids. The only species of aphid which is a pest of glasshouse cucumber crops in the South Holland glasshouse district is *Aphis gossypii*. Cucumber mosaic virus is non-persistent. It may be found in many cultivated plants as well as in weeds. According to Kennedy et al. (1962) this virus may be transmitted by many species of aphids. Tjallingii (1952) and van Koot & van Dorst (1959) state that cucumber crops grown in the early part of the year escape infection as they will have reached a mature stage by the time the aphids take to the wing. Börner (1952) reports that (*Cerosipha*) *Aphis gossypii* Glover from cucumber nurseries was found to be anholocyclic. However,

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in his studies of the *A. frangulae-gossypii* problem, Böhm (1966) comes to the conclusion that part of the population on crops of the cucumber family is holocyclic (overwintering on Rhamnaceae), a smaller part is anholocyclic (overwintering in glasshouses) and a considerable part is killed by frost together with the host plant. Thomas (1968) sees a close relationship between the holocyclic *A. frangulae* Kaltb. and the anholocyclic *A. gossypii*, and suggests that the latter hibernates in glasshouses and other sheltered places. Maison (1966) comes to the conclusion that in S.E. France *Myzus persicae* transmits CMV from weeds into the melon crop in spring and that *A. gossypii* plays an important rôle in the subsequent spread of the virus. According to McClanahan (1964) it is possible under practical conditions for *M. persicae* to transmit the virus into cucumber crops and for *A. gossypii* to spread the disease.

In breeding experiments by Passlow & Roubiceck (1969) with *A. gossypii* on cotton seedlings (temperature 16 to 26 °C), there were found to be four larval stages, each lasting about two days. The adult stage was reached after 7½ days. The adult had an average life span of 16 days (maximum 46 days) during which they produced a progeny of 50 on average and 166 as maximum. Wyatt (1970) reported that *A. gossypii* on cucumber crops multiplied at rates of 5.4, 8.8 and 6.5 times a week at average temperatures of 19.7, 25 and 26 °C, respectively.

As *A. gossypii* plays such an important rôle in the cucumber crops in the South Holland glasshouse district, an investigation was carried out to establish whether there is a relationship between the flights of these aphids and the incidence of CMV. Transmission of this virus by aphids was also studied and the numbers of aphids entering the glasshouses through the ventilators were recorded.

Materials and methods

In order to establish the relationship between the flights of aphids of the *A. gossypii* group and the incidence of cucumber mosaic virus, yellow water traps (36 × 53 cm) were used for several years. The traps were set out at a height of 50 cm. In each season one trap was installed at the Research Station at Naaldwijk where cucumber crops were grown regularly. For a number of years there were also three yellow water traps distributed over a cucumber growing area in the South Holland glasshouse district. In a nursery growing peppers at Poeldijk one trap was placed in a sheltered site between glasshouses at 2 to 7 m distance from the glasshouses. Another one was placed at a cucumber nursery at Delft and a fourth trap on an allotment at Maasdijk. For comparison a fifth trap was placed in an area where no cucumbers were grown. This was on meadowland of a farm at Negenhuizen near Schipluiden. The traps at Poeldijk, Delft, Maasdijk and Negenhuizen were 4.2 km NE; 9.7 km E; 3.4 km S and 9.3 km SE, respectively, of the Research Station at Naaldwijk.

In 1965 and 1966 some yellow water traps were placed in a few glasshouses right under the ventilators, in order to obtain information about the numbers of aphids entering the glasshouse. Ventilators and traps were isolated from the rest of the glasshouse by fine gauze and the crops were kept free of aphids so that no

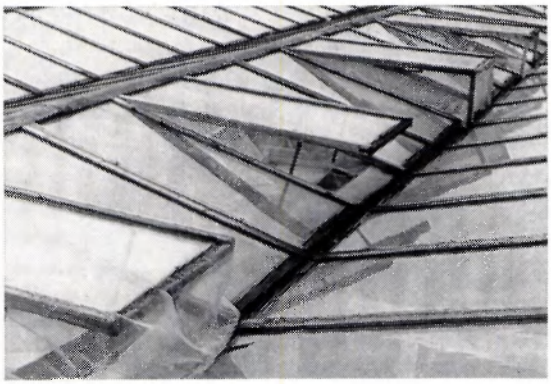

Fig. 1. Yellow water traps under ventilators, some of which are covered by nylon gauze.

aphids could enter the traps from the glasshouse. Half of the traps were covered on top with nylon gauze of 0.9 mm mesh (see Fig. 1). The ventilators could be closed if necessary, but this rarely happened in summer.

A preliminary investigation was carried out into the possibility that aphids penetrate into the glasshouse through crevices between the panes. This was done by fixing on the inside of the glasshouse sticky tape over four crevices between the panes and over a few crevices between the concrete foundations and the lowest pane of glass. It should be pointed out that in well-maintained glasshouses the latter crevices are usually sealed.

As cucumber mosaic virus is non-persistent, it is not easy to determine which aphid species are responsible for transmitting the virus to cucumber crops under practical conditions. Nevertheless, an attempt was made to find out more about the agents of infection by placing young cucumber (Sporu) and gherkin (Baarloo Non-Spot) plants in the open and under frame lights (permanently opened to 25 cm) for 24 h. This was done several times a week in several summers. The plants were marked and all the aphids removed at the end of the 24-hour period and before the plants were taken back to the glasshouse. The aphids collected from the plants consisted of alatae, their larvae and other apterous aphids. Few of the latter were found. Only the alatae were counted and identified. After the exposure the plants were grown on for three weeks in an aphid-proof glasshouse to determine which plants, and how many, had been infected with CMV during exposure. Gherkins were also used as cucumbers are susceptible to bad weather. At the time of the exposure all the plants were in the first true leaf stage. Although they had been sown on the same days, the total leaf area of the young plants (cotyledons, first leaf and youngest leaf) was on average 76 cm^2 for cucumbers and 54 cm^2 for gherkins. For comparison a yellow water trap with a yellow surface area of 1908 cm^2 was placed near the plants.

A. gossypii belongs to a group of aphid species which are very difficult to identify when they are not living on their host plants. In this publication the name *A. gossypii* is used, but the authors are well aware that it would be more correct to refer to the *A. gossypii* group. Identification of the aphids to determine which

of them belonged to the *A. gossypii* group was carried out by comparing the aphids with specimen breeding on cucumbers and by assessing various characteristics such as the number of caudal hairs, the length of the tibial hairs, the number of rhinaria and the marginal tubercles. Dr D. Hille Ris Lambers was kind enough to supply details of these characteristics. All the observations recorded relate to alatae.

Results

Observations on A. gossypii in various places and on flight curves

The catches in the five yellow water traps are shown in Table 1, together with the number of *A. gossypii* expressed as a percentage of the total number of aphids caught. Table 1 shows a wide variation in the numbers of aphids in different places. Delft is the main cucumber area but, against all expectations, the numbers of *A. gossypii* caught there were low compared with those trapped at Naaldwijk and Poeldijk. Also as a percentage of the total number of aphids caught, the numbers of *A. gossypii* recorded at Delft were low. The low figures recorded for Negenhuizen were to be expected, but those recorded for Maasdijk were not. It was therefore impossible to show a relationship between the extent of the cucumber crop in an area and the number of *A. gossypii* trapped. Possibly the degree of shelter provided to the traps had a considerable effect on the catches.

Apart from a few forerunners, *A. gossypii* only begins to have some significance in June. The numbers generally increase in July and August and decrease again in September and October. This is illustrated by the flight curve recorded at Naaldwijk in 1968 (Fig. 2). However, there are exceptions to the rule. There were still large numbers of *A. gossypii* about at Naaldwijk in October 1969, and at Poeldijk in October 1966 and 1969, which led to a clear double-peaked flight curve at Poeldijk in 1969.

Table 1. Numbers of *A. gossypii* and their percentages of the total numbers of aphids caught in yellow water traps.

Year	Naaldwijk		Poeldijk		Delft		Maasdijk		Negenhuizen	
	number	%	number	%	number	%	number	%	number	%
1965	455	6	—		—		—		—	
1966	2 751	18	4 794	15	333	7	564	8	—	
1967	774	5	6 075	7	90	2	96	1	28	0
1968	1 438	14	5 457	9	82	2	220	4	101	1
1969	1 135	7	11 037	12	—		—		—	
1970	799	4	—		—		—		—	
1971	519	3	—		—		—		—	
1972	120	2	—		—		—		—	
1973	393	3	—		—		—		—	

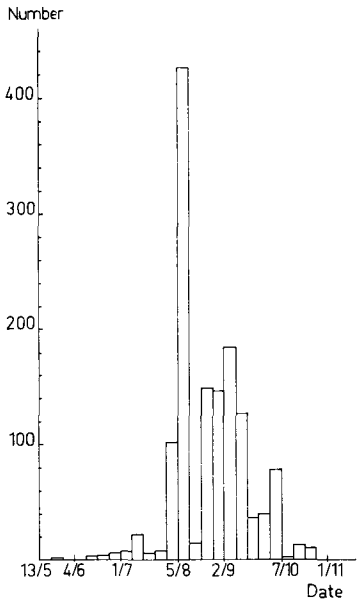

Fig. 2. Numbers of A. gossypii caught in the yellow water trap in the open at Naaldwijk in 1968.

Penetration of winged aphids in glasshouses

At Naaldwijk, in 1965, two yellow water traps were installed in each of three glasshouses containing cucumbers, tomatoes and melons, respectively. In each glasshouse a screen of gauze was placed over the ventilator above one trap, whilst the other was left unscreend.[1] In 1966, four traps were installed in a cucumber house and four in a tomato house. In each set of traps, two were of type A, two of type B (Fig. 1). In Table 2 the catches in these 14 traps are compared with the catches

Table 2. Penetration of aphids via glasshouse ventilators in 1965 and 1966.

Location	Number of traps	Average number of aphids per trap	Average number of *A. gossypii* per trap	Average number of *M. persicae* per trap	% *A. gossypii*	% *M. persicae*
Indoors, Type B[1]	7	729	368	39	51	5
Indoors, Type A	7	165	124	3	75	2
Indoors, cucumbers	6	583	401	22	69	4
Indoors, tomatoes	6	384	140	23	36	6
Indoors, melons (1965)	2	230	100	12	43	5
Indoors	14	447	246	21	55	5
In the open	2	10.539	1.570	611	15	6

[1] Traps under a screen are called Type A, those under unscreened ventilators Type B.

recorded in a trap in the open during the same periods in 1965 and 1966, i.e. 28 June until 11 October in 1965 and 31 May until 14 October in 1966.

The figures 729 and 10 539 in the third column of Table 2 show that in the seven Type B traps in the glasshouses an average of 7 % of the total number of aphids recorded in the open was caught. In Type A traps the number was further reduced from 729 to 165. The same was true for *A. gossypii* of which the number caught was reduced from 368 to 124 by screening of the ventilators. The numbers of *M. persicae* trapped indoors were low, 39 in Type B traps and 3 in the Type A traps. This species was found in practically the same percentages in the Type B traps and in the open, viz 5 % and 6 %, respectively. This is not the case with *A. gossypii* for which the percentages recorded were 51 % and 15 %, respectively. A comparison of the catches in the two indoor traps set-ups showed that in Type A traps 75 % of the aphids consisted of the *A. gossypii* group, 2 % of *M. persicae* and 23 % of other species, whilst in the Type B traps the proportions were 51, 5 and 44 %, respectively. Screening probably reduced the percentage of other species trapped indoors because aphids of the *A. gossypii* group are smaller and therefore find it easier to penetrate the screens. There is a tendency that proportionately more of the medium-sized. *M. persicae* are caught in the Type B traps than in Type A traps (5 % and 2 %, respectively). The percentages of *M. persicae* recorded in the traps in cucumber and tomato houses were practically the same, viz 4 % and 6 %, respectively. This was not the case with *A. gossypii* for which the percentages were 69 % and 36 %, respectively. It appears therefore that *A. gossypii* has a preference for cucumber houses. Only in 1965 two traps were installed in a glasshouse with melons. In that year the total number of aphids of *A. gossypii* and *M. persicae*, penetrating into the melon house showed the same interrelation as those entering the cucumber house. The low figure of 230 in the third column of Table 2 was caused by the fact that in 1965 fewer aphids came into the glasshouses than in 1966.

Two winged and 11 wingless aphids entered the glasshouse through crevices between the panes – four crevices of 45 cm long and at a height of 76 cm – between 24 April and 1 October. During the same period, 11 winged and 160 wingless aphids were caught on the sticky tape over two 45 cm long crevices between the lowest glass and the glasshouse footing, at a height of 20 cm. Out of the totals of 11 and 160, respectively, 2 winged and 84 wingless aphids were caught on the sticky tape on the two occasions when the grass outside the glasshouse was mown.

Infection of cucumber and gherking plants with CMV

Cucumber and gherkin plants were placed in the open and under open frame lights for 24 h to determine the CMV infection risks. In 1966, 1967, 1969 and 1970, the treatment was applied on 41, 39, 44 and 36 days, respectively. The results are shown in Tables 3 and 4.

Table 3 shows the total number of aphids found in the plants as well as the number of *A. gossypii*. The ease with which *A. gossypii* colonises cucumber and gherkin crops is clearly shown in this Table if one compares the percentages of *A. gossypii* found on the plants, and in a yellow water trap nearby. More aphids

Table 3. Numbers of aphids found on cucumber and gherkin plants compared with the numbers caught in a yellow water trap.

Year	Crop and yellow trap	Location	Number of aphids	Number of *A. gossypii*	% *A. gossypii*
1966	20 cucumbers	frames	340	329	97
	20 gherkins	outdoors	2390	2226	93
	yellow trap	outdoors	3801	671	18
1967	20 cucumbers	frames	53	41	77
	20 cucumbers	outdoors	737	558	76
	yellow trap	outdoors	4652	219	5
1969	10 cucumbers	frames	77	56	73
	10 gherkins	frames	34	25	74
	10 cucumbers	outdoors	873	536	61
	10 gherkins	outdoors	574	407	71
	yellow trap	outdoors	3876	414	11
1970	10 cucumbers	frames	60	48	80
	10 gherkins	frames	77	56	73
	10 cucumbers	outdoors	413	223	54
	10 gherkins	outdoors	339	178	53
	yellow trap	outdoors	6184	244	4

were found on the plants in the open than on those under the frame lights. There was no clear difference between cucumbers and gherkins. In each case the proportion of *A. gossypii* was slightly higher for the plants under the frame lights than for the plants in the open.

Table 4 shows the number of plants on which aphids were found and the number of plants on which *A. gossypii* was found. The number and percentage of plants affected by CMV are also shown.

According to Table 4, 18 plants that had no aphids nevertheless were found to be CMV-infected, which is equivalent to 0.4 % of the total number of plants on which no aphids were found. (Out of the total number of 6400 plants used, 1644 were found to have aphids.) In contrast, the rate of CMV infection in the plants on which aphids were found was 7.2 %, or 18 times as high as the percentage previously mentioned. This proves the important rôle of the aphids. Most of the aphids found were *A. gossypii* which is known to transmit the virus. Aphids were found on 118 plants, or 87 %, of the 136 plants that were subsequently found to be CMV-infected. Eighteen, or 13 %, of the plants became infected though no aphids were found on them.

Table 4 also shows that in 1966 the rate of infection was much higher than in subsequent years. This may have been caused by a larger number of aphids per plant or by a higher percentage of aphids carrying CMV. In one 24-hour period – on 11 August 1966 – an exceptionally large number of aphids was found on 20 gherkin plants in the open, viz 1585 *A. gossypii* and 13 of other species. At this high infectation rate 70 % of the plants became infected. On the same date only

Table 4. CMV infection of cucumber and gherkin plants.

Year	Crop	Number of plants used	Number of plants with aphids		Number of plants with aphids and CMV	Number of plants without aphids but with CMV	Percentage plants with aphids and CMV	Percentage plants without aphids but with CMV
			total	*A. gossypii*				
1966	cucumbers	820	117	109	38	6	32.5	0.9
	gherkins	820	344	266	56	6	16.3	1.3
1967	cucumbers	1560	326	266	5	1	1.5	0.1
1969	cucumbers	880	314	238	5	0	1.6	—
	gherkins	880	221	169	0	0	—	—
1970	cucumbers	720	177	139	10	1	5.6	0.2
	gherkins	720	145	104	4	4	2.8	0.7
Total		6400	1644	1291	118	18	7.2	0.4

185 *A. gossypii* were found on the 20 cucumber plants in the frame, but even so, 70 % of these plants also became infected. On that day 216 *A. gossypii* and 7 *M. persicae* were caught in the yellow water trap in the open. Except for 11 August, the average number of aphids per plant was about the same as in the other years.

The aphid density was calculated only for the plants on which aphids were found. The average in 1966 was 1.6 aphids per plant under the frame lights and 2.4 for plants in the open. In subsequent years these averages varied between 1.0 and 1.6, and 2.7 and 3.5, respectively. From this one may conclude that in 1966 a higher percentage of the aphids was infected with CMV than in later years. As in 1966 a very high percentage of the aphids found on the cucumber and gherkin plants consisted of *A. gossypii*, viz 97 % and 93 %, respectively (Table 3), it may be concluded that this aphid played an important part in the transmission of the virus.

The aphids found on the 118 CMV-infected plants were identified: 28 plants had one *A. gossypii*, 55 more than one, 30 had *A. gossypii* together with other species, and 5 other species only. The latter occurred only in plants which had been in the open. *A. gossypii* was therefore by far the most prevalent species. Other aphids found on cucumbers and gherkins varied according to the season. None of the species was dominant, not even *M. persicae*. Of the 136 plants 12 became infected at a time when *M. persicae* was not found in the trap in the open.

Of the 136 CMV-infected plants, 4 infections were recorded in June, 7 in July, 83 in August, 37 in September and 5 in October.

Yearly observations were made of the extent of CMV infection in autumn cucumbers in practice which was found to vary from light to moderate infections. In 1966, the most cases of CMV infection were recorded, both in the experiments and in practice, but the rate of infection was not as severe as in 1963.

Discussion

Autumn cucumbers are sown in July and planted in the beginning of August. The crop is cleared in November. The flight observations show that in the South Holland glasshouse district *A. gossypii* occurs mainly during the period of the autumn crop. The records for two years show that proportionately more *A. gossypii* were found in yellow water traps in glasshouses (55 %) than in traps in the open (15 %). Also, more *A. gossypii* were found in a trap in a cucumber house (69 %) than in a tomato house (36 %). These differences were not found in the case of *M. persicae* for which the figures were 5 %, 6 %, 4 % and 6 %, respectively. It would be desirable to analyse in how far the rate of aphid penetration in cucumber and tomato houses is caused by differences in crop attraction or by differences in the climatic conditions near the ventilators.

At the time of the investigation it was usual for growers to protect the crop against bees by screening the ventilators with gauze, in order to prevent fertilization of the cucumbers. Since the introduction of the all-female flowering varieties, gauze screening is not used any more. The type of gauze used was insufficient to exclude

A. gossypii, and a finer one would have affected the climatic conditions to an unacceptable degree.

Although *M. persicae* is prevalent in the South Holland glasshouse district, the species appears to have little importance for the transmission of CMV in cucumbers. On the 118 plants on which aphids were found and which subsequently became CMV infected, only 5 individuals of *M. persicae* were recorded, four of them together with *A. gossypii*. In the period in which most of the plants were infected, August, *A. gossypii* has a flight peak. As a rule, the largest numbers of *M. persicae* are found in the second half of July.

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