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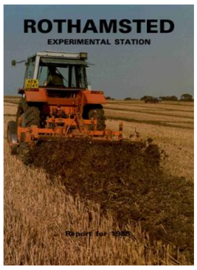

Yellow Cylindrical Sticky Aphid Traps at Rothamsted and Broom's Barn With Particular Reference to the Study of Yellowing Viruses Affecting Sugar Beet

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Yellow cylindrical sticky aphid traps at Rothamsted and Broom's Barn with particular reference to the study of yellowing viruses affecting sugar beet

G. D. HEATHCOTE*

Abstract

The numbers of *Myzus persicae* and of *Aphis fabae* caught on sticky cylindrical aphid traps at Rothamsted and at Broom's Barn in the years 1974 to 1980 are presented, completing an unbroken record covering more than 40 years at Rothamsted and 21 years at Broom's Barn. The numbers caught at the two sites are compared and related to the incidence of yellowing viruses of sugar beet both locally and nationally. The times at which these aphids were first caught in spring by the sticky traps and suction traps or found by fieldstaff of British Sugar on sugar-beet plants are also compared.

Introduction

Yellow cylindrical sticky traps were used at Rothamsted for more than 40 years and at Broom's Barn for 21 years to record the times at which aphids fly, which can be of great importance when developing control strategies for viruses affecting agricultural crops. These sticky aphid traps were first used at Rothamsted by Doncaster and Gregory (1948), who showed that it was migrant winged aphids in June that were mainly responsible for spreading virus in potato crops. Their first traps were painted white and were 90 cm long, but from 1946 the traps were shortened to 30 cm. From 1948 onwards the sticky traps used at Rothamsted and elsewhere were painted yellow (Broadbent, *et al.*, 1948) because these catch more aphids than white traps. The shade of the yellow paint of the traps affects both the size of the sample and its species composition. For the traps at Rothamsted and Broom's Barn a brilliant yellow of the Hansa group (called 'Canary Yellow' by the manufacturers, B.S. 0-001) was used (Taylor & Palmer, 1972). Sticky traps have now been superceded by suction traps (Taylor, 1974, 1977, 1979; Taylor *et al.*, 1981) at Rothamsted and Broom's Barn, because the catch of a suction trap is less affected by changes in the weather, larger numbers are caught, also because the aphids caught can be sorted and identified more easily from a suction than a sticky trap.

The sticky trap catches provide a unique unbroken measure of the abundance of the peach-potato aphid, *Myzus persicae* (Sulz.) and of the black bean aphid, *Aphis fabae* Scop., on a weekly basis over a long period. Records of the trap catches up to 1973 have aleady been published (Broadbent & Heathcote, 1961; Heathcote, 1966 and 1974). The records from Rothamsted and Broom's Barn, which are about 80 km apart, are now extended to 1980; in addition they are compared with those from suction traps of the Rothamsted Insect Survey (RIS) (Taylor, 1977).

Methods

Broadbent (1948) concluded that a single yellow sticky trap, carefully sited, was enough to show the main periods of flight of *M. persicae*. For the data given below, a single trap was placed each year among small experimental plots of several different crops at Rothamsted, and another in plots of unsprayed sugar beet at Broom's Barn; the traps were set with the bottom of the cylinder 1·5 m from the ground and had a trapping surface of 945 cm^2 (Broadbent *et al.*, 1948).

Suction traps have been operating continuously at 12·2 m over a grass sward at Rothamsted and Broom's Barn since 1965. Details of sites, assumptions, procedures, and

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standardization of sampling have already been published (Taylor, 1974, 1977, 1979; Taylor *et al.*, 1981).

British Sugar fieldmen make an estimate of the incidence of virus yellows in their areas throughout the growing season, based on plant counts made in randomly-selected crops ('specific field' counts) (Hull, 1968; Bardner, French and Dupuch, 1981). There were 17 beet sugar factories in England during most of the period covered by this paper. Rothamsted was originally in the Felsted factory area but is now within the enlarged Ipswich sugar factory area. Broom's Barn is in the Bury St Edmunds factory area.

Results

Numbers of *M. persicae* trapped at Rothamsted and Broom's Barn. The weekly catches of *M. persicae* on the sticky traps from May to October inclusive in 1974 to 1980 are shown in Tables 1 and 2. The mean annual catches were 37 (Rothamsted) and 58 (Broom's Barn); in comparison, for the sticky trapping period 1960–80, the means were 44 at Rothamsted and 49 at Broom's Barn. In contrast, when suction traps were operating at both sites in the period 1965 to 1980, the average weekly catch of *M. persicae* from May to October was 193 in the suction trap at Rothamsted and 290 in the suction trap at Broom's Barn. There was no regular pattern of annual abundance, probably because of the existence of both anholocyclic and holocyclic populations affected by varying weather, but during the period reported here in detail there were more than the long-term average number of *M. persicae* trapped each year from 1974 to 1976 and fewer each year from 1977 to 1980.

During the period when there were both sticky and suction traps at both sites (1965 to 1980) there was a correlation between the numbers of *M. persicae* (log $n+1$) trapped during May and June ($r=0{\cdot}70$, $P>0{\cdot}01$) but not between the total numbers caught from May to

TABLE 1

Weekly catches of M. persicae *and* A. fabae *on sticky traps at Rothamsted, 1974–80*

	M. persicae							*A. fabae*						
Week	1974	1975	1976	1977	1978	1979	1980	1974	1975	1976	1977	1978	1979	1980
May 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	1	1	0	0	0	0	1	0	0	0	0	0	0
3	5	0	11	0	0	0	0	2	0	0	0	0	0	0
4	5	0	6	0	0	0	1	4	0	2	0	0	0	0
June 1	7	0	2	0	0	0	0	6	0	0	0	1	0	0
2	4	0	2	0	0	0	0	2	0	2	0	0	0	0
3	12	1	9	0	0	0	1	17	0	3	0	1	1	0
4	5	1	8	0	0	0	0	66	0	54	0	0	6	0
July 1	10	3	10	1	0	0	1	106	1	4	3	1	7	0
2	3	38	1	1	0	0	0	216	1	9	6	0	95	0
3	1	72	0	2	0	0	0	128	26	0	46	21	15	0
4	0	8	0	4	1	0	1	65	105	1	32	20	324	2
Aug 1	0	0	0	0	0	0	0	69	152	0	472	9	179	1
2	0	0	0	4	0	0	0	143	1	1	104	41	37	1
3	0	0	0	1	0	0	0	5	0	0	129	2	2	0
4	2	0	0	0	0	0	0	11	1	0	0	0	0	0
Sept 1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
2	2	0	0	0	0	0	0	2	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0	0	0	1	1
Oct 1	0	0	2	0	0	0	—	0	0	0	0	0	1	—
2	0	—	2	—	4	0	—	0	—	0	—	0	0	—
3	0	—	—	—	—	—	—	0	—	—	—	—	—	—
4	0	—	—	—	—	—	—	0	—	—	—	—	—	—
Total	56	124	55	14	5	0	5	843	287	76	793	96	768	5

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TABLE 2

Weekly catches of M. persicae *and* A. fabae *on sticky traps at Broom's Barn, 1974–80*

	M. persicae							*A. fabae*						
Week	1974	1975	1976	1977	1978	1979	1980	1974	1975	1976	1977	1978	1979	1980
May 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
3	8	1	7	0	0	0	0	1	1	0	0	0	0	0
4	5	1	2	0	0	0	2	1	0	0	0	1	0	0
June 1	7	1	6	0	0	0	1	2	0	0	0	0	2	0
2	1	0	18	0	0	0	4	0	1	0	0	1	0	0
3	12	3	20	0	0	0	4	2	0	0	0	0	0	0
4	31	3	40	0	0	0	8	98	0	2	0	0	2	0
July 1	30	2	3	2	0	0	18	466	0	1	0	1	1	0
2	40	32	0	1	0	0	3	806	0	0	1	4	15	1
3	7	40	0	6	0	0	1	129	0	1	20	22	121	0
4	0	18	0	2	0	8	5	58	16	0	14	180	1210	0
Aug 1	0	0	0	2	0	0	1	74	33	0	124	109	736	1
2	0	0	0	0	0	2	1	32	1	0	240	52	185	0
3	0	0	0	0	2	0	0	10	0	0	26	7	5	0
4	0	1	0	0	2	0	0	4	0	0	1	1	0	0
Sept 1	0	0	0	0	0	0	0	3	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	2	0	0	0	1	0	0
Oct 1	0	0	0	0	1	0	0	2	0	0	2	0	0	0
2	0	0	0	—	0	0	0	1	0	0	—	0	0	0
3	1	1	0	—	—	—	—	0	0	0	—	—	—	—
4	0	0	0	—	—	—	—	1	1	0	—	—	—	—
Total	142	94	96	13	5	10	48	1693	53	4	428	379	2177	2

October at the two sites (r=0·35 NS). Differences in the farming practices in the two areas probably contributed to the difference in the numbers trapped from July to October. For example, the experimental plots of sugar beet at Broom's Barn were usually a long way from the concentrations of alternative host crops for *M. persicae,* but in 1976 many *M. persicae* developed on unsprayed potatoes at Broom's Barn (on 25 June there were 6126 *M. persicae* on a 100-leaf sample, including 183 winged adults), and this crop was clearly the source of a large catch at Broom's Barn when there were no heavily-infested potatoes near the trap at Rothamsted and its catch was relatively small. Similarly, at Broom's Barn in 1980 a neighbouring farmer grew oilseed rape, an overwintering host plant for the aphid, within 500 m of the sticky trap and this may account for the large catch of *M. persicae* in July (which is when rape plants are shedding leaves and are becoming unsuitable as food for aphids). There were no rape crops near the Rothamsted trap in 1980 and the catch of *M. persicae* there was small.

The catches from the suction traps at the two sites during May and June 1965–80 were very closely correlated (r=0·93, P>0·01). However, unlike the situation with the sticky traps, there was also a significant correlation between the numbers caught throughout the entire season at the two sites (r=0·65, P>0·01). The suction traps appear to reflect changes in the numbers of *M. persicae* in the air over a large area, whereas sticky trap catches may show local differences in their numbers.

Numbers of *A. fabae* trapped at Rothamsted and Broom's Barn. The weekly catches of *A. fabae* on sticky traps at the two sites from May to October in 1974 to 1980 are shown in Tables 1 and 2. The average numbers of *A. fabae* caught during the season were 11 times larger than those of *M. persicae,* 410 at Rothamsted and 677 at Broom's Barn; this is similar to the 21

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year average viz. 533 at Rothamsted and 523 at Broom's Barn. There was, however, no significant correlation between the numbers caught during May and June at the two sites.

Years when *A. fabae* were abundant tended to alternate with years when they were few, and years with more than 1000 *A. fabae* trapped were always followed by years in which fewer than 100 were trapped. This tendency to alternation of 'high' and 'low' *A. fabae* years can most probably be attributed to the density dependent effect of parasites and predators on the almost entirely holocyclic population (cf. Jones & Dunning, 1972).

In the suction traps the total catches of the entire season in the period 1965 to 1980 were similar (r=0·69, P>0·01), and especially so from the beginning of May until mid-June, when the main migration from spindle to sugar beet is completed (r=0·77, P>0·01). Thus, as with *M. persicae*, suction trap catches are probably less affected by local sources of host plants and aphids than sticky trap catches.

First records of the season. Table 3 shows that *M. persicae* were most often caught earlier by the suction traps at 12·2 m (which sample a large volume of air) than by the yellow sticky traps.

TABLE 3

Weekly period up to the second week of June in which M. persicae *and* A. fabae *were trapped at Broom's Barn and Rothamsted, 1968–80*

		Suction trap						Sticky trap					
		May				June		May				June	
Year	Site (Week number)	1	2	3	4	1	2	1	2	3	4	1	2
1968	Broom's Barn (BB)				+					+			
	Rothamsted (RES)				+	+	+				+	+	+
1969	BB						○			○			○
	RES					○	○			○	○		○
1970	BB			+			+				+		
	RES						*				+		
1971	BB			+	*	+	*			○	*	○	
	RES			+	*	+	*		+		○		+
1972	BB			+		+	+					+	
	RES			+	+		*			+	+		
1973	BB			+	+	*	*				○	*	○
	RES			+	*	*	○			*	○	○	○
1974	BB			+	*	*	*			*	*	*	+
	RES			*	+	*	*		○	*	*	*	*
1975	BB				+	*	*		+	*	+		*
	RES		+	+		*	+		+				
1976	BB	+	+	+	+	*	*			+	+	+	+
	RES	+		*	*	*	*		+	+	*	+	*
1977	BB						+						
	RES				+								
1978	BB				○	○	○				○		
	RES					○	+					○	
1979	BB					○	○					○	
	RES						○						
1980	BB			+	+	+	+				+	+	+
	RES			+	+	+	+				+		

+=*M. persicae*
○=*A. fabae*
*=*M. persicae* and *A. fabae*

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In contrast, the first *A. fabae* of the season was most often caught on a yellow sticky trap, and not in the suction trap. Although both *A. fabae* and *M. persicae* are attracted to yellow, *A. fabae* is attracted twice as strongly (Heathcote *et al.*, 1969).

Virus yellows. The relationship between the incidence of 'virus yellows' in England and the numbers of *M. persicae* caught on a sticky trap at Rothamsted in the period 1942 to 1973 has already been discussed by Heathcote (1974); the paper also gives the numbers of *M. persicae* trapped at Broom's Barn and the incidence of yellows in the area in the period 1965 to 1973. However, the following years (1974 to 1980) are particularly interesting when relating the numbers of winged aphids caught on traps to the incidence of yellowing viruses in the sugar-beet crop because they include the year with the highest (1974) and also with lowest (1979) recorded incidence of 'virus yellows' in England (Table 4).

TABLE 4

Incidence of virus yellows nationally, and in the Felsted and Bury St Edmunds sugar factory areas, and the highest mean aphid populations on sugar-beet plants, 1974–80

	% VY at end of June			% VY at end of July			% VY at end of August			Peak mean aphid population/plant (nationally)*	
Year	National	Felsted	Bury	National	Felsted	Bury	National	Felsted	Bury	Wingless green aphids	Wingless black aphids
1974	2·0	6·6	2·8	41·6	79·2	69·4	65·7	95·9	96·7	3·7	59
1975	0·3	0·4	0·1	6·5	13·1	2·4	36·5	57·4	27·7	6·0	1
1976	0·7	2·1	0·1	8·6	34·0	10·4	18·7	69·1	19·0	1·3	1
1977	0	0·1	0	0·3	1·0	0·2	0·7	4·8	0·4	0·2	1
1978	0	0	0	0·1	0·4	0	0·4	0·9	0·3	<0·1	2
1979	0	0	0	0·1	0·2	0	0·2	0·4	0·2	0·2	64
1980	0	0·2	0	0·4	5·1	0·3	2·0	18·7	1·4	0·5	0
Mean	0·4	1·3	0·4	8·2	19·0	11·8	17·7	35·3	20·8	1·7	18

*Highest record up to mid-July.

1974. The relatively large numbers of *M. persicae* caught early in the 1974 season (Table 1) suggested that the forthcoming attack of yellows would be severe. At the end of June 2·0% of the sugar-beet plants nationally showed yellows, whereas over the previous ten years on average only 0·1% had done so. Both BYV (beet yellows virus) and BMYV (beet mild yellowing virus) spread widely. Sugar-beet plants infected in late May or early June take two to three weeks to develop symptoms of BYV and four weeks or more to develop symptoms of BMYV; late in the season plants take longer to develop symptoms, and may remain symptomless. The viruses must therefore have been introduced by winged aphids in late May or early June.

The wind blew strongly from the south during May 1974 and it is likely that aphids which had overwintered in southern England brought virus into sugar-beet crops further north (Heathcote, 1978). For example, at Broom's Barn between 8 and 11 May the wind blew from the south for 57% of the time, with a mean speed of 19·8 km h^{-1}. The incidence of yellows eventually reached 66% nationally, probably mainly due to spread within the crops, but there may have been further introduction by winged aphids.

1975. Few *M. persicae* were trapped in May and June and only 0·3% of sugar-beet plants showed symptoms of yellows at the end of June. The infestation by wingless green aphids was nearly twice as heavy as in 1974 at the equivalent time. Yellows spread occurred mostly

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during July and this was probably due to wingless green aphids moving from plant to plant in summer drought conditions, but it may also have been due to transmission by winged *M. persicae* which were unusually numerous (e.g. 92 were caught on the sticky trap at Broom's Barn during July).

1976. Approximately as many *M. persicae* were caught on the sticky traps as in 1974, but only 0·7% of beet plants showed symptoms of yellows at the end of June. Only a small proportion of the immigrant aphids may have been infective with yellowing viruses in 1976, or they may have been destroyed by predators, but at the end of August only half as many plants nationally showed yellows as in 1975. However, in the Felsted sugar factory area, which includes Rothamsted, the large number of winged aphids was associated with a serious attack of yellows. The Bury St Edmunds sugar factory area, which includes Broom's Barn, suffered much less from the disease (Table 4).

1977–80. In these four years few winged *M. persicae* were trapped, the population on sugar-beet plants remained small, and there was little spread of virus yellows: however, an increase in the number of winged *M. persicae* trapped in 1980 was again associated with greater spread of yellows in the Felsted area than elsewhere in England (Table 4).

Earlier work established that there was then an approximately linear relationship between the numbers of winged *M. persicae* caught on sticky traps in May and June and the incidence of virus yellows subsequently (Watson & Healy, 1953). Later, the regression equation calculated for the sticky-trap catch of *M. persicae* in May and June at Rothamsted on the incidence of virus yellows nationally from 1946 to 1972 accounted for 41% of the variance (Heathcote, 1974). There was a closer correlation between the incidence of yellows nationally and the catch of *M. persicae* at Rothamsted in May and June in the period 1960 to 1980 ($r=0{\cdot}68$ $P>0{\cdot}05$), and also the number caught at Broom's Barn on a sticky trap ($r=0{\cdot}64$ $P>0{\cdot}05$), as might be expected because the catches at the two sites differed only slightly.

There was a less close relationship between the trap catches and the incidence of virus yellows locally, as shown for example by the regression of the trap catch at Broom's Barn in May and June from 1960 to 1980 on the estimated incidence of yellows in the Bury St Edmunds factory area ($r=0{\cdot}57$, $P>0{\cdot}01$). This is probably because the estimate of the yellows incidence in any one sugar factory area is based on few fields, and is subject to considerable error because there is always great field to field variation. There was no correlation between the annual catch of *M. persicae* and the incidence of yellows at either site.

A. fabae is not generally considered an important vector of virus yellows in England although in the laboratory it can as readily transmit BYV as *M. persicae,* it is not a vector, or only a very poor vector of BMYV (Thielemann & Nagi, 1979). In support of this view, *A. fabae* was abundant in 1974 when yellows spread exceptionally widely, but even more abundant in 1979 when there was a little spread in sugar-beet crops (Tables 1, 2 and 4).

Discussion

This paper shows that there can be a positive relationship between the numbers of *M. persicae* caught on yellow cylindrical sticky traps and the incidence of 'virus yellows' of sugar beet in eastern England. BMYV is a persistent virus and the main cause of virus yellows in eastern England, but the semi-persistent BYV is also involved to a lesser extent (Smith & Hinckes, 1983). These viruses may be carried long distances by infective aphids. Non-persistent viruses, such as beet mosaic virus, can be carried by many more species of aphids, but the extent to which they spread depends much more on local sources of infection and their spread is less readily related to the catch of sticky traps (Watson & Heathcote, 1966).

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Aphid trap data can be particularly useful early in the season. It can be important to establish when aphids are first flying in spring when predicting the extent to which virus diseases will spread and giving advice on control measures. Young plants are particularly susceptible to infection and colonization by aphids; Turl (1980) observed that a series of early spring migrations of the peach-potato aphid, *M. persicae*, in Scotland from 1971 to 1976 was associated with an increasingly high incidence of potato leafroll.

Over the past 40 years sticky cylindrical aphid traps have proved to be useful tools in the study of several aphid-borne plant viruses in addition to those of potato and sugar beet for which they were most often used. They have been used for monitoring *Rhopalosiphum padi* (L.) in New Zealand as a basis for forecasting outbreaks of barley yellow dwarf virus (Close, Smith & Lowe, 1964), and for monitoring *Cavariella aegopodii* (Scop.) in the UK to give early warning of carrot motley dwarf virus outbreaks (J. N. Oakley, *personal communication*). However, they have not proved popular in continental Europe where water traps are more widely used, and a recent attempt to establish a common aphid-trapping system using sticky traps for members of the International Institute for Sugar Beet Research (IIRB) in Europe was abandoned in favour of using potato 'trap plants' in sugar-beet crops (Heathcote *et al.*, 1982).

Yellow sticky traps attract aphids and they also catch aphids impacted by the wind. They are cheap to make, can easily be moved, and remain effective for several weeks even if unattended. However, they are unpleasant to handle and it is difficult to extract the catch from the coating of sticky grease (Rogerson, 1975). Although water traps are even cheaper to make and easy to move they require much more frequent attention than sticky traps; they rely almost entirely on colour attraction and are ineffective if they dry up, flood, or become covered with particles of wind-blown soil or dead insects. Both of these types of trap are useful for small research projects, but for larger, longer-term projects, suction traps are preferable because they are less affected by changes in weather. Suction traps are, however, expensive to make and they require a source of electric power.

It is now possible to test aphids for infectivity with certain viruses, e.g. *Aphis gossypii* Glover can be tested for infectivity with cucumber mosaic virus using ELISA (enzyme-linked immunosorbent assay) (Gera, Loebenstein & Raccah, 1978), and *M. persicae* can be tested for potato leaf roll virus using ISEM (immunosorbent electron microscopy) (Roberts & Harrison, 1979), but the body contents of the aphids being tested must be undamaged. Aphids caught in water or suction traps are relatively undamaged, but those caught on sticky traps cannot be tested for virus; this may prove a major disadvantage of using sticky traps in the future, and they may never again be used in a major epidemiological study. However they have provided a unique continuous record of the changes in aphid numbers over many years at Rothamsted, beginning at a time when very little was known about aphid movement and the spread of plant viruses. While sticky traps have been in use there have been major changes in agriculture, such as the use of broad spectrum herbicides (which limit the numbers of weeds acting as reservoirs of aphids and viruses within crops), a recent and large increase in the crop area of oil-seed rape (a host of *M. persicae* and a yellowing virus), and there has also been a great increase in the use of systemic and other insecticides which has been accompanied by the appearance of *M. persicae* which are extremely resistant to some insecticides (Sawicki *et al.*, 1978).

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