Observations on different methods of aphid trapping

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SUMMARY

Cylindrical and horizontal sticky traps painted in a range of spectral colours were used to determine the flight and landing behaviour of aphids. Data are also presented on aphid catches in suction traps at two heights and in light traps. Apart from colour sensitivity (yellow versus white) there was apparently a separate response to colour which in some species varied with season. Within yellow-sensitive species there was also a differential response to colour. With the experimental methods used, it was not possible to define mathematically the active and passive landing components on cylindrical traps. Though the active landing component was large it varied between aphid species. Most species caught on horizontal traps at ground level had been flying above 1 m. In some species the response of males to colour and their landing behaviour differed from that of viviparae and oviparae.

Four years data from suction traps suggest that aphid species can be divided into three categories on the basis of the height at which they normally fly. One group, mostly tree-feeders, always show the greatest density at a high level (12.2 m) throughout the season. The second group always have the highest density at a low level (1 m) whilst a third group of species change at a specific date each autumn from a maximum density at 1-12.2 m. Attraction to light (moth trap) appeared to be linked with the grouping of species by height of flight. The interpretation of catch data is discussed in the light of these observations.

INTRODUCTION

Trapping was initiated at Aberystwyth in 1968 to identify and study the incidence of aphids prior to examining their behaviour in relation to virus diseases of Gramineae. Since the crops to be studied were some distance from electricity supplies, experiments were conducted with sticky traps, and the effect of trap colour and type on the number of aphids caught was examined. In 1969 an attempt was made to assess the active landing component on cylindrical sticky traps and also to obtain information on the height from which aphids were attracted to horizontal traps. From 1969 aphid suction traps and a moth trap were operated in conjunction with the Rothamsted Insect Survey (Taylor & French, 1970), allowing a more accurate determination of aphid incidence, density at different heights and attraction to light.

METHODS

Sticky traps

Two types of sticky trap were used in 1968. Vertical cylindrical traps (Broadbent, Doncaster, Hull & Watson, 1948) 0.3 m long, 0.113 m diameter were placed with the top 1 m above ground level, and horizontal traps 0.3 × 0.4 m set at 0.3 m above ground level, both types having the same trapping area. The trapping surface of both was of plastic sheet coated with Ostico banding grease (Plant Protection Ltd.). Eighteen traps of each type were set at intervals down the slope of an east-west valley (i.e. the

Table 1. *Paints used on traps*

Colour	Visual colour	British standard colour range (BS 2660) code no.	Reflectance (%)
1	Red	0.005	20
2	Orange	0.004	42
3	Orange-yellow	4.055	76
4	Deep yellow	0.003	50
5	Gold	0.002	56
6	Yellow	0.001	72
7	Lime	0.008	56
8	Light green	5.063	20
9	Medium green	5.064	20
10	Blue-green	0.010	20
11	Blue	7.084	30
12	White	White	90
13	Black	Black	0
14	Bright red	Fluorescent coating, range 323, Leyland Paints Ltd.*	
15	Orange		
16	Chrome yellow		
17	Lime		
18	Green		

* No British Standard or reflectance values available for fluorescent finishes.

line of traps was at right angles to the prevailing winds), with vertical and horizontal traps alternating. Eighteen paint finishes (Leyland Paints Ltd.) were randomized separately between the two types of trap (Table 1). All paints were gloss, or, in the case of the fluorescent finishes, varnished, and applied to the trap (not to the plastic covering) strictly in accordance with the manufacturer's instructions. The traps were examined daily and the trapping surfaces renewed weekly, between May and November.

To study the proportion of the trap catch which actively landed on cylindrical traps in contrast to that caught passively (Heathcote, 1957) normal traps were compared with capped and horizontal traps. The cap was a horizontal black disk 0.7 m diameter fixed symmetrically on top of a cylindrical trap. Thus aphids flying above and subtending an angle of less than 45° from the trap axis were not in visual contact with the coloured trapping surface. The horizontal traps were spaced 2 m apart and set at 1 m and 0.7 m above ground level (i.e. level with the top and bottom of the cylindrical traps).

The height from which aphids were attracted to horizontal traps was studied using

yellow water-bowl traps (Moericke, 1951) 0.23 m diameter placed 1.5 m apart. The bowls were exposed at 0.91 m and 0.46 m and at ground level, and also beneath horizontal transparent plastic sheets. The plastic sheets were supported by aluminium frames 2.5×2.0 m and set at 0.91 and 0.46 m, with the bowls beneath at 0.46 m and ground level, and at ground level, respectively. Both trials were set up over broad red clover kept cut to a maximum height of 50 mm. In both trials the treatments were randomized, replicated twice, with the traps set in a row at right angles to the prevailing winds. The traps were removed from any aerodynamic obstruction and tests with smoke showed that the horizontal caps and plastic sheets did not disturb horizontal air flow. The traps, which in both experiments were painted yellow (British Standard Colour Range (BS 2660) colour no. 0.001), were examined daily between July and November 1969, except during periods of rain, when the bowls were not operated.

Suction traps

As part of the Rothamsted Insect Survey a 12.2 m suction trap was erected in April 1969 and operated continuously with a smaller trap at 1 m above ground level. The catch was collected daily at 10.00 h from April to November inclusive, and weekly during the remainder of the year. The nominal intake of the 12.2 m trap was 2858 m³/h (Taylor & Palmer, 1972) and of the 1 m trap 1132 m³/h.

Light trap

Also in conjunction with the Insect Survey, a moth trap was operated daily at the same site from 30 min before sunset to 30 min after sunrise throughout the year using a 200 W tungsten filament bulb. From 1970, all aphids caught were identified.

RESULTS

For the species caught most frequently in 1968, histograms of the total catch for each colour (transformed $\log(n+1)$) and trap type are given in Fig. 1. Table 2 presents the significance levels for the various factors. Since there were no replicates, both first-order interactions were used to test each main effect and the second-order interaction used to test the first-order interactions for significance. Of the six species with sufficient data for analysis (all females) only *Rhopalosiphum oxyacanthae* (Schr.) (*insertum* (Walk.)) did not show a significant response to trap colour. The remainder all showed a response when tested against the colour $\times$ months interaction, indicating that colour had an overall effect irrespective of the response to time of year. However, when tested against the colour $\times$ trap-type interaction, only *Aphis fabae* Scop. gp. gave a significant response to colour, suggesting that only in *A. fabae* gp. was there a colour response irrespective of the effects of months or trap type, whilst the response to colour by the rest was influenced by trap type. When tested against the second-order interaction, all except *R. oxyacanthae* were significant.

The high significance of months with all species when tested against the colour $\times$ months interaction reflects the occurrence of flight peaks not affected by the response to colour. When months were tested against the months $\times$ trap-type interaction only

Fig. 1. Aphid catches on coloured traps, 1968. Numbers of colours refer to Table 1; 1-11, red to blue; 12, white; 13, black; 14-18, fluorescent red to green. —, cylindrical traps at 1 m; ·····, horizontal traps at 0.3 m.

Macrosiphum (Sitobion) avenae (Fabr.) gave a significant response, suggesting that trap type was having a strong effect on the response of the other species whilst *M. (S.) avenae* responded to months in numbers trapped irrespective of the other factors.

Table 2. *Analysis of trap catches, June–October 1968 (transformed $\log(n+1)$): variance ratios*

Factor	D.F.	Species			
		<i>Aphis fabae</i> gp.	<i>Capitophorus</i> <i>hippophaes</i>	<i>Cavariella</i> <i>aegopodii</i>	<i>Rhopalosiphum</i> <i>oxyacanthae</i>
Months analysed	...	June, July, Aug.	July, Aug., Sept.	June, July, Aug.	Aug., Sept., Oct.
Trap colour	17	† 7.64*** ‡ 4.13**	3.71*** 1.38	4.85*** 1.86	1.70 0.97
Months	2	† 149.87*** § 6.83	77.05*** 7.08	40.90*** 1.07	104.93*** 18.01
Trap type	1	† 49.11*** § 4.11	4.94* 1.22	51.14*** 3.49	106.63*** 32.17*
Colour × months	34	2.64**	1.05	1.42	0.73
Colour × trap type	17	4.89***	2.82**	3.69***	1.29
Months × trap type	2	58.37***	11.44**	53.94***	4.28*
Second-order interaction	34				
Total	107				

Factor	D.F.	Species	
		<i>Macrosiphum (S.)</i> <i>avenae</i>	<i>Rhopalosiphum</i> <i>padi</i>
Months analysed	...	June, July, Aug., Sept.	June, July, Aug., Sept.
Trap colour	17	† 2.69** ‡ 1.52	17 2.82** 1.80
Months	3	† 172.52*** § 31.75**	4 19.89*** 3.32
Trap type	1	† 46.18*** § 14.98*	1 47.38*** 12.37*
Colour × months	51	0.94	68 2.36**
Colour × trap type	17	1.63	17 3.69***
Months × trap type	3	5.03**	4 14.15***
Second-order interaction	51		68
Total	143		179

Main factors tested against: † colour × months, ‡ colour × trap type, § months × trap type.
Significance levels: * 5 %, ** 1 %, *** 0.1 %.

Significantly, more aphids were caught on the cylindrical than on horizontal traps, shown when trap type was tested against the colour × trap type interaction; the effect operated irrespective of the response to colour, though the significance was low with *Capitophorus hippophaes* (Walk.). However, when trap type was tested against the months × trap type interaction only *M. (S.) avenae*, *R. oxyacanthae* and *R. padi* (L.) were significant at a low level, suggesting that with all species the response to trap type was influenced by months.

In two species time of year influenced the colours to which they were attracted. A higher proportion of *A. fabae* gp. were caught on colours 8, 10, 11, 14 and 15 in September than in July, and the converse occurred with colour 5. With *R. padi* fewer aphids were caught in the later months on colours 1, 4, 8, 9, 10, 11, 13 and 14 than on the other colours, colour 17 caught less in July than the others and 12 (white) more in June in proportion to the catch on the other colours later in the year. There was a significant interaction between trap colour and type for all species analysed except *M. (S.) avenae* and *R. oxyacanthae* (Table 2). For all species there was a significant interaction between trap type and time though the significance was low with *R. oxyacanthae*. The proportion of aphids caught on horizontal compared with cylindrical traps increased with lapse of time in *C. hippophaes*, *M. (S.) avenae*, *R. oxyacanthae* and *R. padi* but decreased with *A. fabae* gp. and *Cavariella aegopodii* (Scop.).

Table 3. Trap colour for maximum catch on sticky traps

Species	Cylindrical trap at 1 m		Horizontal trap at 0.3 m	
	Gloss finish	Fluorescent finish	Gloss finish	Fluorescent finish
<i>Aphis fabae</i> gp.	7	17	7	17
<i>Capitophorus hippophaes</i>	2	15	6	17
<i>Cavariella aegopodii</i>	12	17	6	18
<i>Macrosiphum euphorbiae</i>	6	17	6	16
<i>M. (Sitobion) avenae</i>	4	16	9	15, 17
<i>Metopolophium dirhodum</i>	3, 4	17	—	—
<i>M. festucae</i>	6	15	—	—
<i>Myzus (Nectarosiphon) persicae</i>	12	17, 18	—	—
<i>Rhopalosiphum oxyacanthae</i>	—	—	—	—
♀	2	14	6	15
♂	4	17	11	17
<i>Rhopalosiphum padi</i>	—	—	—	—
♀	7	17	6	16
♂	7	17	6, 7	17

Where a colour is not given, insufficient data available.

If colour sensitivity is defined by the number of aphids landing on white compared with yellow (Moericke, 1955), then from the data for horizontal traps (Fig. 1), *A. fabae*, *Capitophorus hippophaes*, *M. (S.) avenae* and *R. padi* ♂ and ♀ are yellow-sensitive, whilst *Cavariella aegopodii* and *R. oxyacanthae* ♂ are insensitive. *R. oxyacanthae* ♀ are probably yellow-sensitive on the basis of a lower catch on white than black, and their behaviour with fluorescent finishes. Other species found to be yellow-sensitive were *Metopolophium dirhodum* (Walk.), *Metopolophium festucae* (Theo.) and *Macrosiphum euphorbiae* (Thom.), whilst *Anoecia corni* (Fabr.) and *Elatobium abietinum* (Walk.) were insensitive. The results suggest three responses to colour-sensitivity between yellow and white a differential response between colours independent of the yellow/white sensitivity, and within yellow-sensitive species an interaction of trap type and colour (the catch on horizontal traps reflecting the numbers caught on the cylindrical traps throughout the spectrum, as in *M. (S.) avenae*, or being unrelated, as in *R. padi*). The colours giving the maximum catch for each species (Table 3)

clearly show differences in colour sensitivity of some aphids between cylindrical and horizontal traps and also between grass-feeding species (*Macrosiphum* (*S.*) *avenae*, *Metopolophium dirhodum*, *Metopolophium festucae*, *R. oxyacanthae* and *R. padi*). Table 3 also shows differences in colour sensitivity between the sexuales of *Rhopalosiphum* species.

Landing component on cylindrical traps

Table 4 shows the numbers of aphids caught on normal cylindrical, capped and horizontal traps, together with the goodness of fit for the theoretical relationships between these traps. The effect of the caps was marked, the mean reduction for all

Table 4. Mean catches, normal (*N*) and capped (*C*) cylindrical and horizontal (*H*) traps, and the relationship between them, July–November 1969

Trap	Mean catches						χ^2 of relationship between traps				
	<i>N</i>	<i>C</i>	H_t	H_b	S.E.		$N = C + H_t$	$N = C + \Sigma H$	$N = C + \bar{H}$	$N = C + 0.28H_t$	$N = C + 0.28\bar{H}$
<i>Aphid fabae</i> gp.	46.0	4.5	7.0	4.0	3.74		20.70	15.12	23.14	29.78	30.66
<i>Capitophorus hippophaes</i>	19.0	8.0	3.5	4.5	1.68		1.84	0.26	1.58	3.58	3.47
<i>Ceruaphis eriophori</i>	16.0	3.0	8.0	8.0	2.77		0.92	0.67	0.92	5.43	5.43
<i>Macrosiphum euphorbiae</i>	81.5	14.5	17.0	—*	2.50		22.12	—	—	38.40	—
<i>Myzus</i> (<i>Nectarosiphon</i>) <i>persicae</i>	13.0	8.0	7.0	—*	1.58		0.14	—	—	0.40	—
Pemphiginae											
<i>Asiphum tremulae</i>	66.0	11.5	16.5	11.5	1.78		15.36	6.66	17.93	30.25	31.38
<i>Pemphigus</i> spp.	22.5	10.5	14.0	6.0	2.89		0.08	1.21	0.09	1.76	2.35
<i>Rhopalosiphum oxyacanthae</i>											
♀	70.0	42.5	22.5	16.0	9.53		0.18	0.80	0.52	3.77	4.15
♂	20.5	7.0	9.0	3.0	1.47		0.55	0.06	1.68	2.00	4.78
<i>Rhopalosiphum padi</i>											
♀	58.5	27.5	77.0	53.5	4.17		12.98	45.73	7.75	0.78	1.52
♂	45.0	5.5	32.0	37.0	6.61		0.68	7.28	0.29	15.63	14.73

* Trap not operative during period of flight peak and omitted.

species being 68.9%. Therefore in all species a large proportion of the catch on cylindrical traps appears to be attracted from above the trap, the proportion varying between species. Where sufficient males (*Rhopalosiphum*) were caught, they were found to be more affected by the presence of the cap. The numbers of aphids caught differed significantly between the normal trap (*N*), capped trap (*C*) and the horizontal traps (H_t and H_b , top and bottom horizontal) with all species except *Ceruaphis eriophori* (Walk.), *Myzus* (*Nectarosiphon*) *persicae* (Sulz.) and *R. oxyacanthae* ♀. Theoretically the catch on the normal cylindrical trap should correspond with that on the capped trap plus a component of the horizontal traps representing the area of the cylindrical trap obscured in the horizontal plane by the cap. This obscured area has a maximum value of $0.28H$ and for aphids flying both above and below the level of the trap the expected relationship should be $N = C + 0.28H_t$ or $N = C + 0.28\bar{H}$. Table 4 shows

the χ^2 for these and other combinations of N , C and H . Only in the case of *R. padi* ♀ was the theoretical relationship $N = C + 0.28H$ a better fit than the other combinations. In all other cases a larger horizontal component than the expected was required to satisfy the theoretical relationships.

Water traps

Table 5 shows the mean trap catch from July to November of aphids caught in the Moericke bowls at different heights and under plastic covers. With the exception of *R. oxyacanthae* ♀, all species were caught significantly more frequently in the exposed

Table 5. *Mean catch in water traps exposed and under plastic covers at different heights, July–November 1969*

Trap height (m)	Exposed			Cover at 0.9 m		Cover at 0.46 m	S.E.
	0.9	0.46	0	0.46	0	0	
<i>Aphis fabae</i> gp.	47.5	62.5	86.5	19.5	58.5	30.0	13.3
<i>Capitophorus hippophaes</i>	9.0	6.5	25.5	1.5	16.0	5.0	4.5
<i>Ceruaphis eriophori</i>							
♀	7.0	12.0	4.0	4.5	5.5	1.5	2.3
♂	5.5	9.5	4.5	0	1.0	0	1.8
<i>Cryptomyzus galeopsidis</i>	1.0	3.5	9.5	1.5	5.5	1.5	1.7
<i>Hyperomyzus lactucae</i>	1.0	3.5	24.5	2.0	7.5	4.5	2.5
<i>Macrosiphum euphorbiae</i>	91.0	196.0	217.5	30.5	80.5	23.5	13.6
<i>Metopolophium dirhodum</i>	3.5	4.5	7.5	4.0	16.0	11.5	1.7
<i>Myzus (Nectarosiphon) persicae</i>	13.5	29.0	82.5	7.5	27.5	10.0	8.0
<i>Rhopalosiphum oxyacanthae</i> ♀	8.5	4.0	1.5	4.0	2.0	1.0	2.0
<i>R. padi</i>							
♀	61.0	37.0	17.0	3.5	4.0	1.5	5.6
♂	32.0	24.0	6.5	0	1.5	0	3.5

traps than in the corresponding traps under cover. Only *Capitophorus hippophaes*, *Macrosiphum euphorbiae* and *Metopolophium dirhodum* showed differences at ground level between the different covers, suggesting that these species were flying mostly between 0.91 and 0.46 m, the remaining species flying above this height when attracted by the traps. More *Rhopalosiphum* spp. were caught at 0.91 m than at ground level, reversing the sequence of catch/trap height shown by other species; since the trapping period included the main autumn flight peak – this suggests migratory flight commencing in the vicinity of the traps rather than host-finding flight (Johnson, 1969).

Suction traps

Since the suction traps had different air intakes, the data for the 1 m trap were corrected to correspond with that at 12.2 m. The numbers of aphids caught are given as weekly totals transformed to log n . The dating convention was for each week to commence on a Monday, the weeks starting from the first Monday in January (week 1). Weekly catches of five aphids or less have been ignored. The catches for three years (Figs. 2–4) show three recurring patterns based on the density at either height (ignoring exceptions of one week's duration which did not recur in other years).

(1) *Species which always showed a higher density at 12.2 m throughout the year.*

(*Tuberculoides annulatus* (Hartig), Pemphiginae in Fig. 2, also *Drepanosiphum platanoidis* (Schr.).) Species in this group are typically tree-feeding aphids found in Forestry Commission plantations on the upper slopes of hills surrounding the trapping site. *Elatobium abietinum* may belong to this group, but was trapped early in the year for a limited period and the data are consequently inconclusive.

Fig. 2. Weekly suction trap catches of *Rhopalosiphum padi*, *Tuberculoides annulatus* and *Pemphigus* spp.; — at 1 m; ----, at 12.2 m.

(2) Species which always showed a higher density at 1 m throughout the year. (*Cavariella aegopodii*, *Macrosiphum* (S.) *avenae* and *M. euphorbiae* (Fig. 4), also *Cavariella pastinacae* (L.), *Cavariella theobaldi* (Gill. and Bragg) and probably *Cavariella archangelicae* (Scop.) which was restricted to weeks 20–27, *Hyadaphis foeniculi* (Pass.), *Hyperomyzus lactucae* (L.), *Macrosiphum rosae* L., *Metopolophium dirhodum*, *M. festucae* and *Microlophium* spp.) Species in this group usually occurred on plants growing in the vicinity of the trap site, and were characterized by occurring in lower numbers in the traps than species in the other groups.

(3) *Species which initially had a higher density at 1 m and changed at a specific date to a higher density at 12.2 m.* (*R. oxyacanthae*, *R. padi*, *Brachycaudus helichrysi* (Kalt.) Figs. 2 and 3). The members of this group and the weeks in each year when the change in height occurred are given in Table 6. Species in this group occurred on crops in

Fig. 3. Weekly suction trap catches of *Rhopalosiphum oxyacanthae* and *Brachycaudus helichrysi*; — at 1 m, ---- at 12.2 m.

the vicinity of the trapping site and were frequently caught in large numbers. *Phorodon humuli* (Schr.) is normally trapped at Aberystwyth between weeks 22 and 26; however, in 1971 it was also caught later in the year and on this evidence probably belongs in this group.

Myzus (N.) persicae is probably a variant of group 3. Although trapped in low numbers, the incidence was similar in each of the 4 years. The weekly totals for the first 3 years combined (transformed to $\log(n+1)$, Fig. 4) show that the first change to a

higher density at 12.2 m occurred during week 35, was reversed during week 37, reverted to a higher density at 12.2 m during week 40, reversed once more during week 41, and finished with a higher density at 12.2 m from week 44.

Fig. 4. Weekly suction trap catches of *Cavariella aegopodii*, *Macrosiphum (S.) avenae*, *M. euphorbiae* and *Myzus (N.) persicae*; — at 1 m, ---- at 12.2 m.

Table 6. Weeks in which the density of aphids trapped changed from being highest at 1 m to being highest at 12.2 m

Species	1969	1970	1971	1972
<i>Aphis fabae</i> gp.	35	37	37	35
<i>Brachycaudus helichrysi</i>	35	36	35	35
<i>Capitophorus hippophaes</i>	36	36	39	38
<i>Macrosiphum (Sitobion) fragariae</i>	39	39	39	39
<i>Rhopalosiphum oxyacanthae</i>	37	37	37	38
<i>R. padi</i>	36	36	36	38

Week 36 commenced on 8 September in 1969, 7 September in 1970, 6 September in 1971 and 4 September in 1972.

Catches to light

Table 7 gives a summary of aphids caught from 1970 to 1972 in the Rothamsted Insect Survey moth trap. Catches of aphids were associated with peaks of aphid flight as shown by the suction traps, but did not show a constant relationship, being caught either the night before, on the same night or the night after flight peaks. Tree-feeding, including 'group 1' species, and species in 'group 2' tended to be attracted to light throughout the season, whilst the species of 'group 3' (excluding *B. helichrysi*, which was never caught at light) were caught only in the later part of the season. This incidence of 'group 3' species at light apparently corresponded to the change in height at which they were caught, reported above.

Table 7. *Summary of aphids caught in the Rothamsted Insect Survey moth trap at Aberystwyth*

Week	Tree-feeding species including 'group 1'			'Group 3' species			Other species including 'group 2'		
	1970	1971	1972	1970	1971	1972	1970	1971	1972
21	0	0	0	0	0	0	0	0	1
22	0	2	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0
24	0	2	0	0	0	0	0	0	0
25	1	3	0	0	0	0	0	0	0
26	0	24	0	0	0	0	0	0	1
27	0	1	0	0	0	0	1	0	0
28	0	0	1	0	0	0	0	0	2
29	3	3	1	0	0	0	0	0	2
30	0	10	1	0	0	0	0	0	0
31	0	10	0	2	0	0	18	0	0
*									
35	0	0	28	0	0	22	0	0	2
36	0	1	0	0	0	0	0	0	0
37	0	0	0	2	0	0	0	0	0
38	0	0	9	0	57	3	0	5	2
39	0	2	1	0	28	0	0	7	1
40	0	12	0	0	19	1	0	4	0
41	1	1	2	64	39	13	0	1	1
42	0	0	1	5	3	1	0	0	0
43	0	0	0	0	5	0	0	0	0
44	0	0	1	0	5	0	0	1	0
45	0	0	0	0	0	0	0	0	0
46	0	0	0	0	1	0	0	0	0
Total	5	71	45	73	157	43	19	18	12

Tree-feeding species: *Cinara cupressi* (Buckt.), *Chaitophorus populeti* (Panz.), *Drepanosiphum platanoidis*, *Elabobium abietinum*, *Euceraphis punctipennis* (Zett.), *Myzocallis castanicola* Baker, Pemphiginae and *Tuberculoides annulatus*.

'Group 3' species: *Aphis fabae* gp., *Capitophorus hippophaes*, *Macrosiphum* (*S.*) *fragariae* (Koch), *Myzus* (*N.*) *persicae*, *Rhopalosiphum oxyacanthae* and *R. padi*.

Other species, including 'Group 2': *Aulacorthum solani* (Kalt.), *Capitophorus eleagni* gp. (Del. Guer.), *Cavariella pastinacae*, *Cavariella theobaldi*, *Ceruaphis eriophori*, *Holcaphis frequens* (Walk.), *Macrosiphum* (*S.*) *avenae* and *Metopolophium dirhodum*.

* No aphids caught at light weeks 32-34 inclusive.

DISCUSSION

Moericke (1969) confirmed the existence of colour vision in aphids and suggested that aphids, like humans, perceive colour in terms of hue, tint and intensity. He showed that not only were different species able to differentiate between pure unsaturated colours (i.e. without any tint caused by the addition of white), but that they also respond differentially to tints of a given colour and that the response varied at different times of day. The effect of trap colour on aphid catches may have been due to differences in the intensity of reflected light. The covering of plastic coated with banding grease would have reduced the reflectance of each colour and the difference in reflectance between colours. The reflectance of ultraviolet from some lead-base paints was eliminated due to the absorption by banding grease (Entwistle, 1963). For this reason catches were not corrected for the manufacturer's reflectance values (Table 1). The data show that with most species some colours attracted greater numbers of aphids than others with higher reflectance values. Moreover, in some cases where the reflectance value of colours was the same there were still differences in the numbers of aphids caught. Thus despite possible effects due to the intensity of reflected light, there appears to have been an overriding response due to trap colour. Moericke (1955) showed that some aphid species sensitive to colour during the landing phase (yellow versus white) also differentiated between colours. Cartier & Auclair (1964) have shown a similar response with feeding apterae. The experiments reported here showed both colour sensitivity and differentiation between colours in some species whether caught on horizontal traps or when caught passively or actively on cylindrical traps. Further, in some yellow-sensitive species the response differed between the two types of trap with months and with colours. This was probably due to the alternation between summer and autumn migrants, and supports Moericke's (1969) suggestion that with alternation of host plants gynoparae should show a different reaction to colour than summer migrants. The results also show that the response by males to colour differs from that of oviparae and viviparae on both trap types. There were also differences in behaviour between the sexes in the two trials on landing response. Taylor & Palmer (1972), on the basis of a comparison of yellow-bowl and suction-trap catches at the same height and site, have suggested that grass-feeding species are not yellow-sensitive. Whether this is a better criterion for judging colour sensitivity than Moericke's is debatable, but the results presented show some grass-feeding species to be both yellow-sensitive and to differentiate between colours.

The capping experiment showed that the active landing component of the catch, as against that caught by impaction (Heathcote, 1957) on cylindrical traps, varied between species and could not usually be defined. This variation between species implies that it was due to colour attraction. The inability to define the attracted component mathematically was probably due to basing the analysis on catches over an extended period, the coloured traps having shown variations between both trap type and months. However, with *Aphis fabae* gp., *Macrosiphum euphorbiae* and *Rhopalosiphum* spp. the trial included flight peaks, with only a few individuals caught during the rest of the trapping period. The horizontal traps used in this trial may have been too large, since the theoretical area of the cylindrical trap visible to an aphid in the landing phase was

0.28H. Costa & Lewis (1968) have shown a linear relationship between horizontal trap size and catch, but a correction was not appropriate here since the catch on horizontal traps was in any case less than expected. The trial on the height from which aphids were attracted to horizontal traps showed that most species caught at ground level were originally flying in a zone mainly above 1 m. This experiment does, however, suggest that the missing component on the capped cylindrical traps may have been due to aphids flying below 1 m and inhibited from actively landing by the presence of the black cap, which may have decreased the intensity of the colour of these traps.

The seasonal changes of the height at which species fly, as in the response to colour, may have been due to the alternation between summer and autumn migrants. The remarkably specific date at which the change occurred may have been related to the appearance of sexuales. The first *Rhopalosiphum* males were usually caught during the same week in which the change of height of flight occurred, but their numbers did not reach 30% of the population at either height until 3 or 4 wk later. Although female *A. fabae* gp. and *R. padi* changed both their response to colour with time of year and the height of flight, *Capitophorus hippophaes* and *R. oxyacanthae* did not show the colour response, and the two factors are consequently separate. The change of height of flight may be related to migratory flights to winter hosts involving long distance migration. *Phorodon humuli* is unlikely to breed at Aberystwyth and catches are presumed to result from long-distance flight from Herefordshire, whilst the results with the water traps for *Rhopalosiphum* spp. suggest migratory flights originating in the vicinity of the traps. All the species in group 3 are normally holocyclic with alternation of primary and secondary hosts, though this is equally true of some species in group 2 (e.g. *Cavariella*, *Metopolophium* and *Hyperomyzus lactucae*), and a high proportion of *R. padi* over-winter on Gramineae in the Aberystwyth area.

The apparent relationship of change in height of flight and attraction to light is also difficult to interpret. Taylor & Palmer (1972) have suggested that light-trap catches are partly caused by the light source stimulating night flights of newly mature aphids which normally accumulate overnight and are inhibited from flight by inadequate light. This may have been responsible for the catches of species breeding in the vicinity of the trap on grasses, but does not explain the periodicity in these species nor their occurrence in the autumn only. The tree-feeding species caught throughout the season were breeding more than 100 m from the trap and the intensity of illumination received would not have stimulated flight. It is of interest that one of the tree-feeding species caught most frequently to light, *Drepanosiphum platanoidis*, is known to fly at a low level at night (Heine, quoted by Taylor & Palmer, 1972), whereas throughout the season this species (and the other tree-feeding species of group 1) flies at a greater height than the grass-feeding or polyphagous species. These results suggest that some aphid species which are attracted to light (Frost & Pepper, 1957) are being caught when settling at night from altitude, which explains why the 'group 3' species are only attracted to light in autumn, a period when, it is suggested, long-distance migration into and out of the area occurs.

The results underline the difficulties of interpreting aphid catches when using coloured attractant traps, a subject recently reviewed by Taylor & Palmer (1972). Although horizontal traps only attract flying aphids in the landing phase (Heathcote,

1957) and are thus easy to interpret, they catch fewer aphids than the more practical vertical cylindrical traps. Apart from the difficulty of separating the attracted and impacted components of the catch on cylindrical traps, the results show that with some species the attractiveness of a given colour varies with trap type, month and form of the aphid. Attractant traps would therefore appear to be of most value when used for comparative purposes between adjacent crop treatments. Taylor & Palmer (1972) have suggested the use of British Standard 0.001 yellow (colour 6 in the experiments) as standard on coloured traps. These results confirm the highest overall catch of yellow-sensitive species, but it should be remembered that this type of trap underestimates yellow-sensitive species, e.g. *Cavariella aegopodii*. Suction traps, being free of any element of attraction, are assumed to give unbiased estimates of aphid populations, but the results show that some species change their height of flight during the year, so leading to inaccurate assessments of populations when based on single traps at set heights.

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