Evaluation of Coloured Sticky Traps for Monitoring Populations of *Austroasca viridigrisea* (Paoli) (Hemiptera: Cicadellidae) on Cotton Farms

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ABSTRACT Field tests on the colour response of *Austroasca viridigrisea* adults were conducted using square (30 x 30 cm) coloured sticky traps placed in a cotton field. Among the colours tested, adults were attracted most to yellow traps emitting light in the 500-600 nm region (peak reflectance at 560 nm), followed by green and orange, then red, deep blue, black, magenta and true blue. Dilution of yellow with white to produce yellow-white hues resulted in a significant decline in *A. viridigrisea* captures. Reflectance spectra of painted surfaces of enamel colours and also traps with different hues of yellow indicated that *A. viridigrisea* capture rates were directly related to the amount of light reflected in the 500 - 600 nm zone, the wavelength at which peak reflectance of green plants occurs. This positive behavioural response of *A. viridigrisea* to yellow suggests that the leafhopper can discriminate foliage-like hues (500-580 nm) from non foliage-like hues (<500 nm and > 580 nm) and therefore could detect herbaceous foliage on the basis of colour. Significantly higher number of adults were caught at heights between 25-75cm than at 100, 125 and 150 cm above ground level. To monitor flight phenology and populations of *A. viridigrisea* yellow sticky traps should be placed at heights between 25 and 75 cm above ground level.

Introduction

The vegetable leafhopper, *Austroasca viridigrisea* (Paoli) is one of the important early season pests of cotton in Australia. Adults and nymphs feed preferentially on leaves and new regrowth but are more likely to attack mature leaves during the flowering stage of the crop. Severe infestations can produce a stippling effect on leaves and this can cause damage to seedlings and new regrowth, resulting in significant delays in the growth of the plant (Room and Wardhaugh 1977; Forrester and Wilson, 1988). Currently *A. viridigrisea* populations are readily controlled by synthetic sprays applied during the early part of the cotton season for control of *Helicoverpa* spp. and other pests. These insecticides disrupt natural enemies of the pests and eliminate any chance of development of an integrated pest management program for cotton.

With the proposed introduction of transgenic cotton in Australia by the 1996-97 season, it is expected that synthetic insecticide use on cotton against *Helicoverpa* spp. and other pests will be reduced, and *A. viridigrisea* may assume even greater importance since they are not affected by these plants (G. P. Fitt, pers comm.). Therefore, a better understanding of the stimuli to which *A. viridigrisea* adults respond is essential to the development of more effective trapping techniques to reliably estimate the adult numbers and flight phenology for use in control programmes. Coloured traps have been used to monitor populations of many pbytophagous insects in field crops (Ridgway and Mahr, 1986; Mensah and Madden, 1992). The responses of hemipterans to colour have been extensively studied, with most species strongly attracted to green and yellow (Ridgway and Mahr, 1986; Adams and Los, 1989; Mensah and Madden, 1992). However, apart from studies by Alverson *et al.* (1977) and Meyerdirk and Oldfield (1985) who evaluated the effectiveness of colour traps in monitoring leafhopper populations, studies on colour responses of leafhoppers are rare, and the few studies that have been conducted have focussed on host finding behaviour of leafhoppers (Todd *et al.,* 1990). For the vegetable leafhopper, *A. viridigrisea*, no studies on the colour stimuli to which it responds have been conducted.

The purpose of this study was to determine the relative attractiveness of coloured sticky traps to *A. viridigrisea* adults in cotton, and to find a suitable coloured trap to reliably estimate *A. viridigrisea* populations in the field.

Materials and methods

The colour and height preference studies were conducted in a commercial cotton farm at Auscott Narrabri, using field trapping techniques similar to those of Prokopy (1972). The traps consisted of aluminium squares (30 x 30 cm) painted on both sides with the test colour, coated with a thin layer of Bird Tangletrap® (The Tanglefoot Company, Grand Rapids, Michigan, USA), attached vertically to a steel rod pushed into the ground. The reflectance characteristics of the colours were measured by a Field Spec™.UV/VNIR (350-1050 nm) visible recording spectroradiometer (Analytical Spectral Devices, Inc., Boulder, CO., USA).

Three experiments were conducted from 1992 to 1994. The first experiment assessed the response of *A. viridigrisea* to 30 x 30 cm square yellow, orange, green, red, deep blue, black, magenta and true blue (Duralex Aust., Pty Ltd, Rydalmere, NSW) painted traps from November, 1992 until May, 1993.

Based on the results of experiment 1, the second experiment assessed the response of *A. viridigrisea* to different hues of yellow painted traps from November, 1993 to April, 1994. The colours tested in that study were yellow and white enamels (Duralex Aust., Pty Ltd, Rydalmere, NSW) and three intermediate hues made by mixing the yellow (Y) and white (W) enamels in the following proportions: 3Y:1W; 1Y:1W; 1Y:3W.

The third experiment determined the optimum height for exposure of the most attractive colour traps identified in experiment 1 in order to maximize trap catch. This evaluation was conducted from November, 1993 until April, 1994. In this study each of the three painted coloured traps were placed at 25, 50, 75, 100, 125 and 150 cms from the ground to the base of the panel. The experiments were arranged in a randomized complete block design of eight (experiment 1), five (experiment 2) and three (experiment 3) colour treatments with three replications. The colour traps were placed 2 m apart in a random order.

A. viridigrisea adults trapped over each 7 day period were collected from each side of the sticky traps and transferred with a pin into a tube containing kerosene. The insects were later sexed and counted under a dissecting microscope. Following each collection, each trap was washed with kerosene, dried in the sun, recoated with Tangletrap adhesive and returned to the field.

Analysis of data: All trap catch data were transformed to ($\sqrt{X} + 0.5$) and submitted to repeated measures analysis of variance (Graphpad Version 2.03, Instat Software Inc., San Diego, California) with the least significant difference test (LSD) used to separate means. Arithmetic rather than transformed means are given in the results.

Results

The colour preference test (experiment 1) between November 1992 and May 1993 showed that yellow traps caught significantly ($P<0.05$) more *A. viridigrisea* adults (8.12 per trap per day) than any of the other colours tested (Table 1). Green and orange colour traps were second in preference. This was followed by red, deep blue, black and magenta, with true blue recording the lowest number of adults captured (Table 1). When comparing different hues of yellow (experiment 2), significantly ($P<0.05$) more *A. viridigrisea* adults were collected on full yellow (Y) than on any of the other hues or white (Fig. 1). This was followed by 3Y:1W and 1Y:1W, the latter not significantly different from 1Y:3W. The white traps caught the least number of adults. During the period of study, 49.2 per cent of the total adults caught on all the coloured traps were males and 50.8 per cent females (Fig. 1). The proportion of trapped males and females on each test colour did not differ significantly ($P>0.05$) within colours during any sample period indicating no preference for colour by sex (Fig. 1). The highest number of *A. viridigrisea* adults were caught in January and colour preference was not affected by season.

The reflectance spectra of the painted surfaces are given in Figure 2. Scanning from 350 to 750 nm indicates maximum reflectance between 500-600 nm region except for full white. The peak reflectance of yellow and the three intermediate hues occurred in the 550 and 560 nm region, and for white at 450 nm (Fig. 2). There was a positive correlation between numbers of *A. viridigrisea* adults caught by traps of each colour and the per cent total reflected light emitted by each of the test colours in the 500 and 600 nm region ($P<0.001$) (Fig. 3).

The optimum height to place either yellow, green or orange traps in the field was between 25-75 cm above ground level for yellow and orange and 25-50 cm for green (Table 2). The least number of adults were caught at 150 cm above ground level for all three colours tested (Table 2). The yellow colour trapped the maximum number of adults at each of the heights tested (Table 2).

Discussion

The results of the experiment show a stronger response of *A. viridigrisea* adults to yellow than any of the other colours tested. When the yellow colour was diluted with 25, 50 and 75 per cent (of total volume) white to produce (3Y:1W), (1Y:1W) and (1Y:3W) yellow-white hues respectively, it reduced the per cent total reflected light emitted in the 500-600 nm region and this resulted in a significant decrease in *A. viridigrisea* capture, indicating the degree to which yellow was attractive to the insects. This positive behavioural response of the insects to yellow suggests that *A. viridigrisea* adults can discriminate foliage-like hues (500-580 nm) from non foliage-like hues (<500 nm and > 580 nm) (Prokopy and Owens, 1983) and therefore could detect herbaceous foliage at least in part on the basis of colour. Yellow appears to represent very bright leaves, and like leaves, it reflects little energy below 500 nm and much between 500-600 nm. Yellow therefore acts as a supernormal stimulus for foliage to many phytophagous insects because it elicits a greater alighting response than colours more closely resembling preferred hosts (Prokopy and Owens, 1983). In studies on colour response of aphids, Mooney and Gulmon (1982) noted that increased responsiveness to yellow aids some aphids in finding young, expanding leaves that are high in nitrogen, and often characterized by a yellow colour. Since *A. viridigrisea* adults prefer to feed on young growing herbaceous leaves, their increased responsiveness to yellow suggests an adaptation to locate their hosts and the sites for feeding. This is important because plants are primarily composed of carbohydrates and the amount of nitrogen is usually limited and unequally distributed (McNeill and Southwood, 1973) so that an adaptation to locate preferred food plants and feeding sites will enhance the success of the species.

Several studies have indicated that many insects are attracted to yellow (Coombe, 1981; Meyerdirk and Oldfield, 1985; Zehnder and Speese, 1987; Adams and Los, 1989) and yellow sticky traps have been used to monitor flight activity and populations of hemipterans (Todd *et al.*, 1990; Meyerdirk and Moreno, 1984; Summy *et al.*, 1986; Adams *et al.*, 1983; Meyerdirk and Oldfield, 1985; Ridgway and Mahr, 1986; Adams and Los, 1989; Mensah and Madden, 1992).

The present study has shown that there was no difference in *A. viridigrisea* preference for colour by sex and that a yellow sticky trap supported by a metal pole 25-75 cm above ground level will serve as an effective trapping system for monitoring the flight phenology and populations of all adults. As well, coccinellids (mostly *Adalia bipunctata* (Linnaeus) and *Coccinella transversalis* (Fabricius) which are major predators of *Helicoverpa* spp., were also captured on full yellow (Mensah unpublished). This means that the large scale employment of these traps must be carefully considered.

Acknowledgements

I thank Wendy Harris for technical support, Messrs. Dave Anthony and Stefan Henggeler (Auscott, Narrabri) for cooperating in this study, Mr Graeme Bell and Dr Alison Specht (Centre for Coastal and Resource Management, University of Southern Cross, Lismore, Australia) for providing the spectroradiometer used in the reflectance measurements, and Dr John Madden (Department of Agricultural Science, University of Tasmania, Hobart, Tasmania, Australia) for reviewing the manuscript. The work was supported by the Australian Cotton Research and Development Corporation (grant DAN 68C).

Table 1. Captures of adult *Austroasca viridigrisea* on different coloured traps in commercial cotton at Auscott in Narrabri 1992-1993.

Colour enamels	Mean catch per trap per day [1] X ± SE	Per cent total reflected light emitted in the 500-600 nm region
Yellow	8.12 ± 0.94 a	26.8
Orange	5.92 ± 0.89 b	13.9
Green	5.87 ± 0.82 b	17.1
Red	5.20 ± 0.82 c	11.8
Deep blue	4.78 ± 0.71 c	7.0
Black	4.60 ± 0.64 cd	5.2
Magenta	4.11 ± 0.62 d	8.7
True blue	3.15 ± 0.52 e	7.7

[1] Means based on counts on 19 dates between 20 November 1992 and 3 May 1993; Three replications of each colour per date.

Means with the same letter are not significantly different ($P < 0.05$), Least significant difference test (LSD).

Table 2. Response of adult *Austroasca viridigrisea* on coloured traps placed at different heights in commercial cotton at Auscott in Narrabri 1993 - 1994.

Trap height (cm)	Mean catch per trap per day [1]		
	Yellow	Orange	Green
	X ± SE	X ± SE	X ± SE
25	6.88 ± 1.09 ab	3.08 ± 0.54 a	3.96 ± 0.71 a
50	6.84 ± 1.19 ab	3.21 ± 0.45 a	3.46 ± 0.45 ab
75	8.53 ± 1.29 a	3.10 ± 0.47 a	3.17 ± 0.42 b
100	5.75 ± 0.94 b	2.29 ± 0.22 b	2.59 ± 0.32 bc
125	4.47 ± 0.81 bc	1.90 ± 0.23 bc	2.03 ± 0.27 cd
150	3.37 ± 0.60 cd	1.47 ± 0.20 c	1.68 ± 0.25 d

[1] Means based on counts on 19 dates between 8 November 1993 and 6 April 1994; Three replications of each colour per date.

Means (within columns) followed by the same letter are not significantly different (P>0.05), Least significant difference test (LSD).

Fig. 1. Captures of *A. viridigrisea* on sticky traps painted with yellow, white, and intermediate hues, from November 1993 to April 1994. ⊠ total, ■ males, □ females. Means with the same letter are not significantly different ($P > 0.05$, LSD test). Error bars represent standard errors.

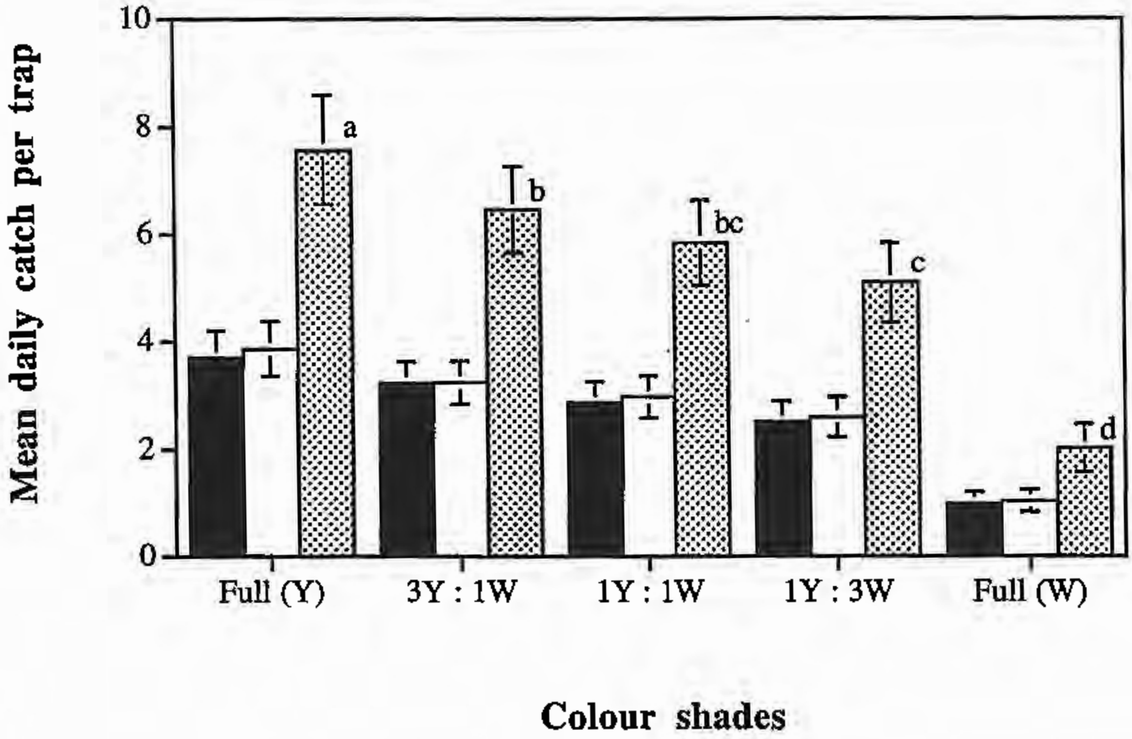

Mean daily catch per trap
0
2
4
6
8
10
a
b
bc
c
d
Full (Y)
3Y : 1W
1Y : 1W
1Y : 3W
Full (W)
Colour shades

Fig. 2. Reflectance spectra of yellow and white enamels and shades. Y = yellow; W = white and Y:W = various mixtures of yellow and white colour enamels.

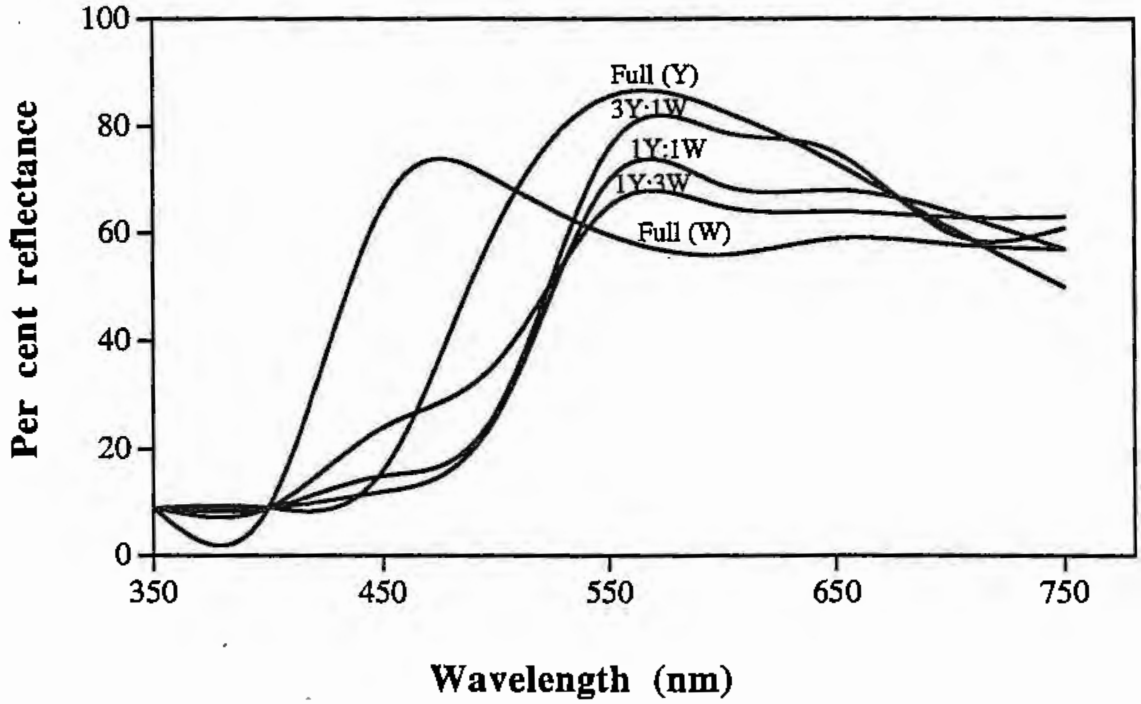
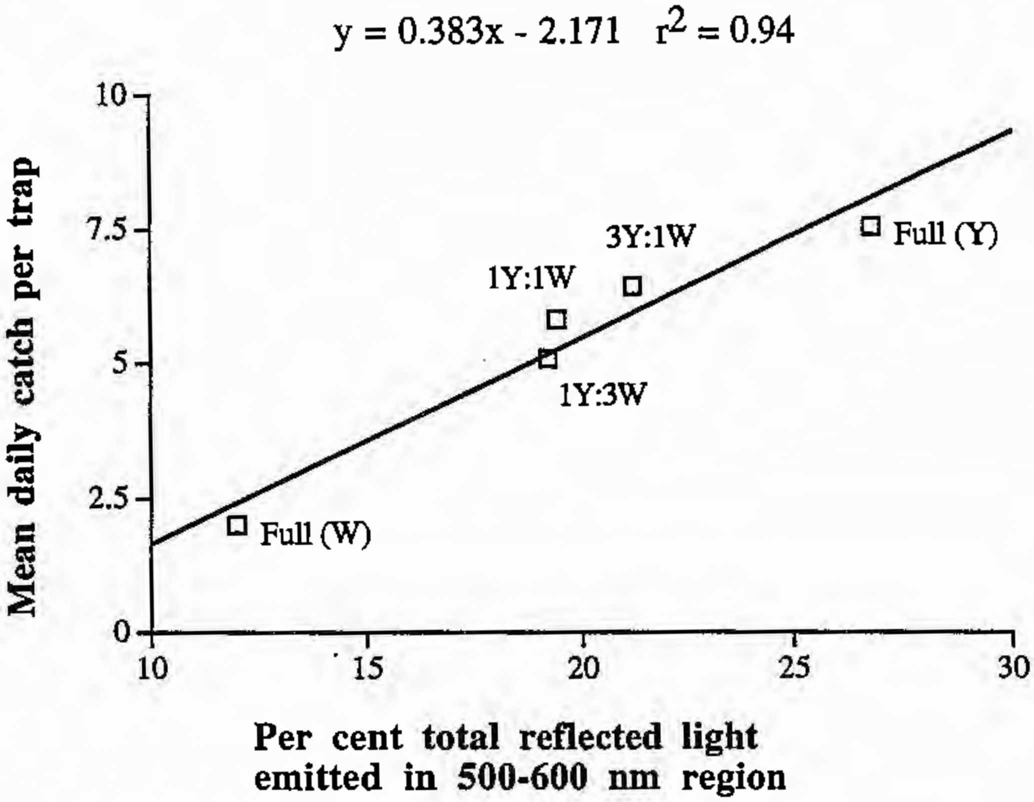

100
80
60
40
20
0
Per cent reflectance
Full (Y)
3Y:1W
1Y:1W
1Y:3W
Full (W)
350
450
550
650
750
Wavelength (nm)

Fig. 3. Relationship between the per cent total reflected light emitted in the 500-600 nm region by white, yellow and intermediate hues and the mean daily catch of *Austroasca viridigrisea* adults in commercial cotton at Auscott in Narrabri from November 1993 until April 1994.



y = 0.383x - 2.171 r2 = 0.94
Mean daily catch per trap
10
7.5
5
2.5
0
10
15
20
25
30
Full (W)
1Y:1W
1Y:3W
3Y:1W
Full (Y)
Per cent total reflected light emitted in 500-600 nm region

References

ADAMS, R. G., DOOMEISEN, C. H. and FORD, L. J. (1983). Visual trap for monitoring pear psylla adults on pears. Environ. Entomol. 12: 1327-1331.

ADAMS, R. G. and LOS, L. M. (1989). Use of sticky traps and limb jarring to aid in pest management decisions for summer populations of the pear psylla (Homoptera: Psyllidae) in Connecticut. J. Econ. Ent. 82: 1448-1554.

ALVERSON, D. R., ALL, J. N. and MATHEWS, R. W. (1977). Response of leafhoppers and aphids to variously coloured sticky traps. J. Georgia Entomol. Soc. 12: 336-341.

COOMBE, P. E. (1981). Wavelength specific behaviour of the whitefly, *Trialeurodes vaporariorum* (Homoptera:Aleurodidae). J. Comp. Physiol. 144: 83-90.

FORRESTER, N. W. and WILSON, A. G. L. (1988). Insect pests of cotton. NSW Agriculture Agfact P5.AE.1: 1-17.

McNEILL, S. and SOUTHWOOD, T. R. E. (1973). The role of nitrogen in the development of insect-plant relationships. *In*: J. Harbourne (ed.). Biochemical aspects of plant and animal coevolution (J.Harbourne ed.). Academic Press, New York, pp. 77-79.

MENSAH, R. K. and MADDEN, J. L. (1992). Field studies on colour preferences of *Ctenarytaina thysanura* in Tasmanian Boronia farms. Entomol. exp. appl. 64: 111-115.

MEYERDIRK, D. E. and OLDFIELD, D. N. (1985). Evaluation of trap colour and height placement for monitoring *Circulifer tenellus* (Homoptera: Cicadellidae). Can. Ent. 117: 505-511.

MEYERDIRK, D. E. and MORENO, D. S. (1984). Flight behaviour and colour trap preference of *Parabemesia myricae* (Kuwana) (Homoptera: Aleyrodidae) in citrus orchard. Environ. Entomol. 13: 167-170.

MOONEY, H. A. and GULMON, S. L. (1982). Constraints on leaf structure and function in reference to herbivory. Bioscience 32: 198-206.

PROKOPY, R. J., (1972). Response of apple maggot flies to rectangles of different colours and shades. Environ. Ent. 1: 720-726.

PROKOPY, R. J. and OWENS, E. D. (1983). Visual detection of plants by herbivorous insects. Ann. Rev. Entomol. 28: 337-364.

RIDGWAY, N. R. and MAHR, D. L. (1986). Monitoring adult flight of *Pholetesor ornigis* (Hymenoptera: Braconidae), a parasitoid of the spotted leafminer (Lepidoptera : Gracillariidae). Environ. Entomol. 15: 331-334.

ROOM, P. M. and WARDHAUGH, K. G. (1977). Seasonal occurrence of insects other than *Helicoverpa* spp. feeding on cotton in the Namoi Valley of New South Wales. J. Aust. Ent. Soc. 16: 165-174.

SUMMY, K. R., GILSTRAP, F. E. and HART, W. G. (1986). Correlation between flight trap response and foliar densities of citrus blackfly, *Aleurocanthus woglumi* (Homoptera: Aleyrodidae). Can. Entomol. 118: 81-83.

TODD, J. L., HARRIS, M. O. and NAULT, L. R. (1990). Importance of colour stimuli in host finding by *Dalbulus* leafhoppers. Entomol. exp. appl. 54: 245-255.

ZEHNDER, G. and SPEESE, J. (1987). Assessment of colour response and flight activity of *Leptinotarsa decemlineata* (Coleoptera: Chrysomelidae) using window flight traps. Environ. Entomol. 16(5): 1199-1202.