Yellow Traps Can Be Used to Monitor Populations of *Coccinella transversalis* (F.) and *Adalia bipunctata* (L.) (Coleoptera: Coccinellidae) in Cotton Crops

R. K. MENSAH

NSW Agriculture, Australian Cotton Research Institute, PMB Myall Vale, Narrabri, N.S.W. 2390.

ABSTRACT During 1992-4, square (30 × 30 cm) sticky traps of various colours were used on a commercial cotton farm to trap adults of *Coccinella transversalis* and *Adalia bipunctata* which are both major predators of *Helicoverpa* spp. Both insects were attracted most to yellow traps which also reflected the most visible light between 500 nm and 600 nm (where green foliage reflects most light). When yellow was diluted with white to produce yellow-white hues, the light reflected between 500 nm and 600 nm was reduced and the numbers of *C. transversalis* and *A. bipunctata* adults caught on these traps were also significantly reduced. This suggests that *C. transversalis* and *A. bipunctata* adults can discriminate foliage-like hues (500-580 nm) from non-foliage-like hues (<500 nm and >580 nm) and are attracted to colours that suggest the foliage of host plants that may harbour their prey. Yellow sticky traps placed 25-50 cm above ground caught significantly more *C. transversalis* and *A. bipunctata* adults than those placed at 75-150 cm and are the most appropriate traps to monitor populations of *C. transversalis* and *A. bipunctata* adults in cotton farms.

Introduction

Coccinella transversalis (F.) and *Adalia bipunctata* (L.) (Coccinellidae) are major predators of *Helicoverpa* spp. (Noctuidae) in cotton in Australia (Room and Wardhaugh 1979; Mensah and Harris unpublished data). Both adults and larvae of the coccinellids feed on the eggs and early stage larvae of the noctuids and if high densities of *C. transversalis* and *A. bipunctata* are established especially early in the cotton season, *Helicoverpa* spp. can be controlled in cotton farms (Mensah and Harris unpublished data). However, *Helicoverpa* spp. are highly migratory and can rapidly infest crops from other sources, so, unless predatory insects are present and well established in high numbers in the cotton crops early in the season before *Helicoverpa* spp. arrive, they cannot respond rapidly enough to control *Helicoverpa* spp. Currently, cotton growers rely solely on visual observation to determine the presence of *C. transversalis*, *A. bipunctata* and other predatory insects in cotton, especially early in the cotton season. Therefore, there is a need to develop a quick and effective trapping technique to monitor populations and to help evaluate the disruptive impact of insecticides on beneficial insects. Developing such a technique requires a better understanding of the role of colour stimuli in the detection of food or host plants that harbour the prey of these coccinellid species. The role of colour stimuli in host detection is becoming more widely recognised (Prokopy and Owens 1983) and coloured traps have been used to monitor populations of many flying insects, especially phytophagous insects in field crops (Kennedy *et al.* 1961; Ridgway and Mahr 1986; Adams and Los 1989; Economopolous 1989; Mensah and Madden 1992). However, studies of the responses of entomophagous insects (viz. predators and parasitoids) to different colours are rarer (Weseloh 1981; Disney *et al.* 1982; Kirk 1984) and no studies have been made of *C. transversalis* and *A. bipunctata*.

The questions to be asked in such a study are:
(1) do *C. transversalis* and *A. bipunctata* adults respond to yellow colour like many other phytophagous insects;
(2) if they do, can yellow sticky traps be used to monitor their population in cotton farms;
(3) what is the optimum height above ground level to place these coloured traps; and
(4) can these two coccinellid species discriminate foliage-like hues from non-foliage-like hues?

To answer these questions, I tested traps with different colours and shades placed at different heights above ground level in commercial cotton farms.

Materials and methods

Responses of *C. transversalis* and *A. bipunctata* to yellow and other enamel colours. The colour response studies of *C. transversalis* and *A. bipunctata* adults were conducted in a cotton farm at Auscott near Narrabri using field trapping techniques similar to those described by Prokopy (1972). The traps consisted of aluminium squares (30 × 30 cm) painted on both sides with the test colour, coated with a thin layer of adhesive glue (Bird Tangletrap®, The Tangletrap Company, Grand Rapids, Michigan, USA), and attached to a vertical steel rod in the ground at 50 cm above the ground.

The reflectance characteristics of the colours were measured with a Field Spec™ UV/VNIR (350-1,050 nm) visible recording spectroradiometer.

The study assessed the response of *C. transversalis* and *A. bipunctata* to traps painted either yellow, orange, green, red, deep blue, black, magenta or true blue from November 1992 until May 1993. The experiments were arranged in a randomised complete-block design of eight colour treatments with three replications. The colour traps were placed vertically and were 2 m apart in a random order.

C. transversalis and *A. bipunctata* adults trapped over 7 d were collected from each side of the sticky traps and transferred to a tube containing kerosene. The insects were later counted under a dissecting microscope. After each collection, each trap was washed with kerosene, dried in the sun, recoated with adhesive and returned to the field.

Responses of *C. transversalis* and *A. bipunctata* to different hues of yellow. Based on the results of the experiment described above, a second experiment was conducted from November 1993 to April 1994 to assess the responses of *C. transversalis* and *A. bipunctata* adults to traps painted with different hues of yellow. The colours tested in this study were yellow and white enamels and three intermediate hues made by mixing yellow and white in the following proportions: 3Y:1W; 1Y:1W; 1Y:3W. The reflectance characteristics of the colours were measured using the spectroradiometer as already described.

The experiments were arranged in a randomised complete-block design of five colour treatments with three replications. The trap size, set up, method and time of sampling of adults from traps were the same as those described above.

Determination of optimum trap height for maximum capture of *C. transversalis* and *A. bipunctata* adults. This trial was conducted in a cotton farm at Auscott near Narrabri from November 1993 until April 1994. In this study, only yellow traps were used. The traps were placed at 25, 50, 75, 100, 125 and 150 cm above ground level. The experiments were arranged in a randomised complete-block design with three replications. *C. transversalis* and *A. bipunctata* were collected from the traps every 7 d and counted as already described.

Analysis of data. All trap catch data were transformed by (X + 0.5) and submitted to analysis of variance. Arithmetic, rather than transformed means, are given in the results.

Results

Responses of *C. transversalis* and *A. bipunctata* to yellow and other enamel colours. Yellow traps caught significantly more *C. transversalis* and *A. bipunctata* adults than any other trap (Table 1). Green and orange traps were the next most effective and true blue, deep blue, red, magenta and black traps were the least effective (Table 1). There was a significant and positive correlation between the amount of light reflected by each colour in the 500-600 nm region and the capture

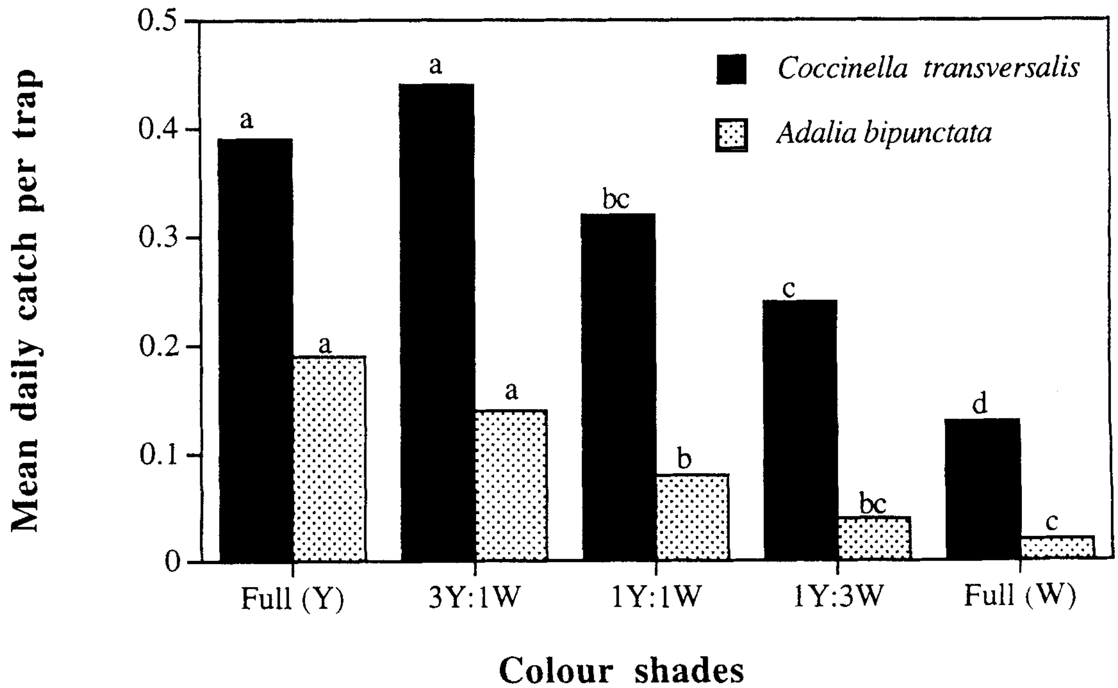


Fig. 1. Captures of *Coccinella transversalis* and *Adalia bipunctata* adults on different hues of yellow coloured traps in commercial cotton at Auscott in Narrabri from November 1993 until April 1994. (Means between treatments for each coccinellid species followed by the same letter are not significantly different ($P > 0.05$) using the least significant difference (LSD) test).

rates of *C. transversalis* ($r^2 = 0.93$; $P < 0.001$) and *A. bipunctata* ($r^2 = 0.94$; $P < 0.001$) (Table 1).

Table 1. Response of *Coccinella transversalis* and *Adalia bipunctata* adults to yellow colours and reflected light emitted between 500-600 nm region on traps in a cotton crop at Auscott, Narrabri 1992-1993.

Colour enamels	Mean catch per trap per day[1]		Per cent total reflected light emitted in the 500-600 nm region
	C. transversalis	*A. bipunctata*	
Yellow	0.35 a	0.23 a	26.8
Orange	0.17 b	0.08 b	13.9
Green	0.23 b	0.11 b	17.1
Red	0.09 c	0.03 c	11.8
Deep blue	0.10 c	0.02 c	7.0
Magenta	0.08 c	0.02 c	5.2
True blue	0.11 c	0.03 c	8.7
Black	0.06 c	0.02 c	7.7

[1]Means based on counts of 19 dates between November 1992 and May 1993; three replications of each colour per sampling date.
Means between treatments within rows followed by the same letter are not significantly different ($P = 0.05$) using the least significant difference tests (LSD).

Responses of *C. transversalis* and *A. bipunctata* to different hues of yellow. Significantly more *C. transversalis* and *A. bipunctata* adults were caught on the full yellow (Y) and 3Y:1W traps than on any of the other hues tested (Fig. 1). The white traps were the least effective. On the yellow traps, the most *C. transversalis* adults were caught in November and the most *A. bipunctata* in February. As the same population trends were seen when both species were sampled visually, colour preference was not affected by season.

The maximum reflectances of the yellow and the white and the intermediate shades occurred between 500 nm and 600 nm (Fig. 2). The light reflected between 500 nm and 600 nm by yellow, white and the three intermediate colours tested was positively correlated with the mean daily trap catches of *C. transversalis* ($r^2 = 0.68$, $P < 0.001$) and *A. bipunctata* ($r^2 = 0.84$, $P < 0.001$) (Fig. 3).

Determination of optimum trap height for maximum capture of *C. transversalis* and *A. bipunctata* adults. The optimum height to place a yellow coloured trap in the field to maximise *C. transversalis* and *A. bipunctata* adult catches was 25 cm or 50 cm above ground (Table 2). At these heights significantly higher numbers ($P < 0.05$) of *C. transversalis* and *A. bipunctata* adults were captured than at 75-150 cm (Table 2). Fewest insects were caught at 150 cm above ground.

Table 2. Yellow trap captures of *Coccinella transversalis* and *Adalia bipunctata* adults at different heights between 25-150 cm above ground level in a cotton crop at Auscott in Narrabri, 1992-1993.

Trap height (cm)	Mean catch per trap per day[1]	
	C. transversalis	*A. bipunctata*
25	4.64 a	2.37 a
50	3.08 ab	1.79 b
75	2.74 bc	0.92 c
100	1.22 c	0.55 cd
125	0.82 c	0.32 d
150	0.53 c	0.13 d

[1]Means based on counts of 19 dates between November 1992 and May 1993; three replications of each colour per sampling date.
Means between treatments within rows followed by the same letter are not significantly different ($P = 0.05$) using the least significant difference test (LSD).

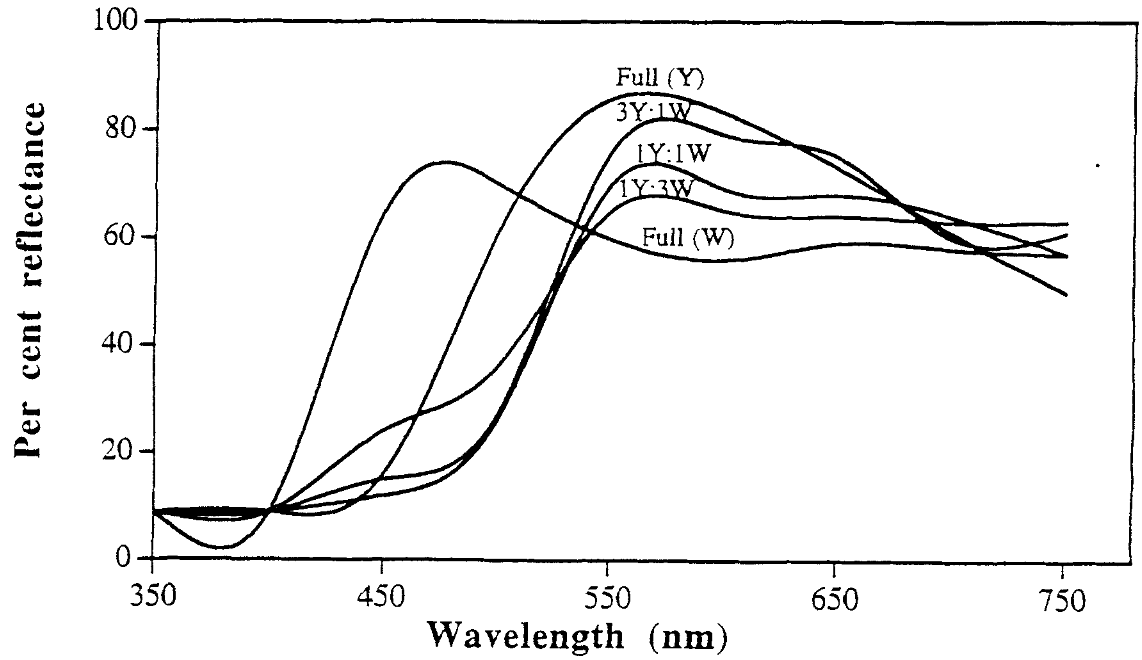
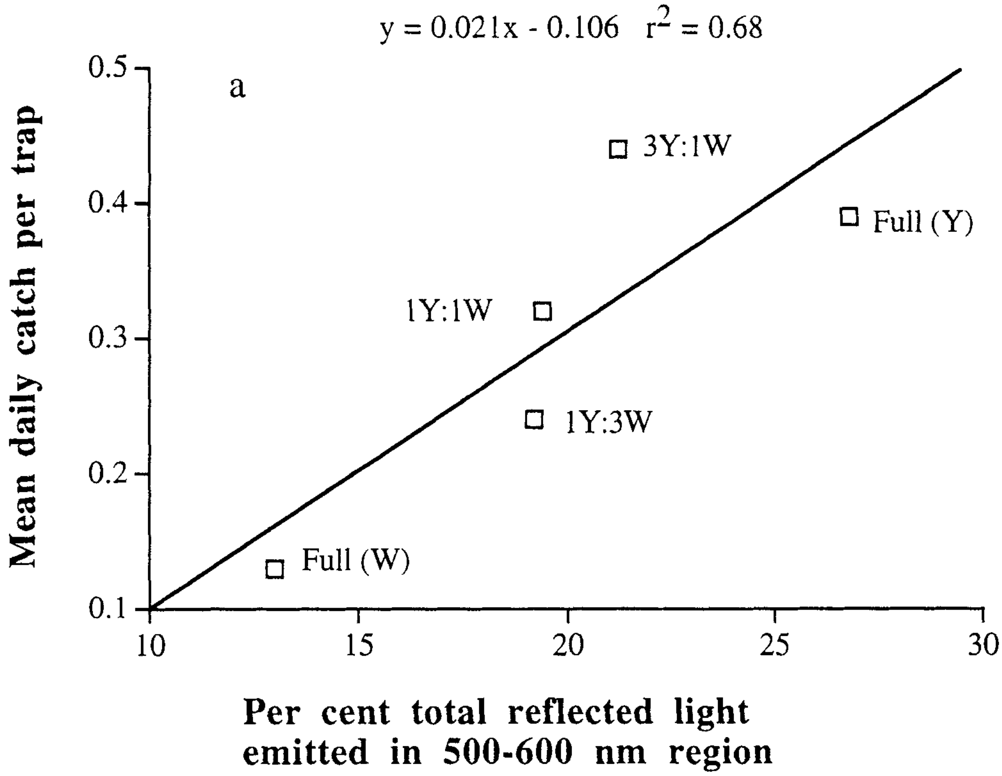


Fig. 2. Reflectance spectra of yellow and white colour enamels and shades. Y = yellow; W = white and Y:W = various mixtures of yellow and white colour enamels.



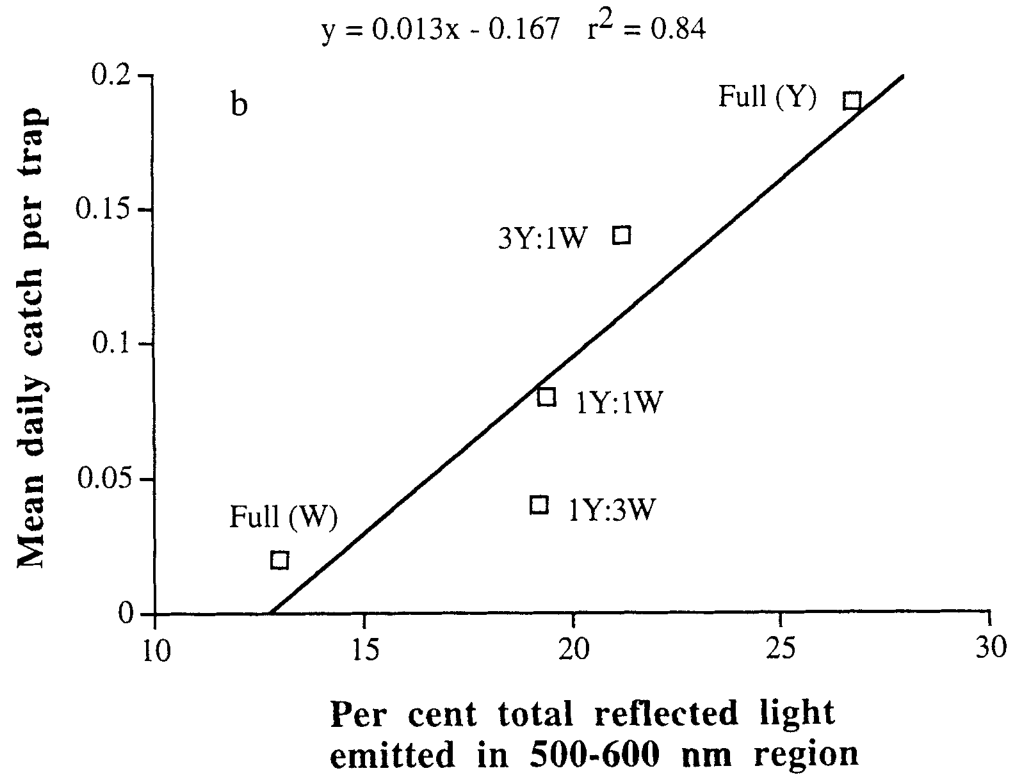


Fig. 3. Relationship between the per cent total reflected light emitted in the 500-600 nm region by each of the test colours and the mean daily trap catch of (a) *Coccinella transversalis* and (b) *Adalia bipunctata* in commercial cotton at Auscott in Narrabri from November 1993 until April 1994.

Discussion

C. transversalis and *A. bipunctata* adults are more responsive to yellow traps than to any of the other colours tested. When full yellow was diluted, the amount of visible light reflected between 500 nm and 600 nm dropped, and presumably, caused the reduction in the number of *C. transversalis* and *A. bipunctata* adults captured. This indicates the degree to which these insects respond to light reflected in the 500-600 nm region.

This positive response of both *C. transversalis* and *A. bipunctata* adults to yellow suggests that these insects can discriminate foliage hues (500-580 nm) from other hues (<500 nm and >580 nm) and would therefore be attracted to the colours of the foliage of host plants that harbour their prey. Leaves reflect little visible energy below 500 nm and much between 500-600 nm, the yellow range. In northern New South Wales, Australia, where short-lived annual crops, including cotton, are grown seasonally, the habitat provided by these crops for phytophagous insects which are preyed upon by *C. transversalis* and *A. bipunctata* will be ephemereal. Such differences in host permanence means that the coccinellids fly periodically to new host locations when their prey's host plant are harvested and so they may use colour stimuli frequently in flights to distinguish foliage that harbours food and thereby ensure their survival.

Many phytophagous insects respond positively to yellow (Wilde 1962; Kring 1967; Prokopy and Boller 1971; Greany *et al.* 1977; Ferro and Sychak 1980; Coombe 1981; Adams *et al.* 1983) and yellow coloured traps have been used to monitor their populations (Meyerdirk and Oldfield 1985; Adams and Los 1989; Mensah and Madden 1992). Entomophagous insects that are not particularly associated with foliage, such as predators and parasitoids, would be expected to show the positive response to yellow if this enabled them to locate the leaf-feeding insects on which they prey. My study has indicated that *C. transversalis* and *A. bipunctata* adults respond to yellow in this way. This could suggest that traps for prey will catch beneficial insects as well and make it possible to monitor populations of both prey and predator using one trap. However, in studies using yellow traps to monitor populations of a specific phytophagous insect where one wishes to avoid the capture of *C. transversalis* and *A. bipunctata* adults, the traps should be located at a height higher than 50 cm above ground. In conclusion, yellow coloured traps placed between 25 to 50 cm above ground in cotton farms could be used to monitor populations of *C. transversalis* and *A. bipunctata*.

Acknowledgments

I thank Wendy Harris, Debbie Colless, Steve Ryman and Ray Morphew for technical support; Messrs Dave Anthony and Stefan Henggeller (Auscott, Narrabri) for co-operating in this study, Dr Robert Brown (Write Way Consulting and formerly at Queensland Department of Primary Industries, Brisbane), Dr G. A. C. Beattie (University of Western Sydney, Richmond) and Dr J. L. Madden (Dept. of Agricultural Science, University of Tasmania, Hobart) for reviewing the manuscript and their constructive criticisms; Mr Graeme Bell and Dr Alison Specht (Southern Cross University, Lismore) for help with the spectroradiometer measurements. The work was supported by Australian Cotton Research and Development Corporation (grant DAN 68C and 89C).

References

Adams, R. G., Doomeisen, C. H. and Ford, L. G. (1983). Visual trap for monitoring pear psylla adults on pears. Environ. Ent. 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.

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

Disney, R. H. L., Erzinclioglu, Y. Z., Henshaw, D. J. C., Howse, D., Unwin, D. M., Withers, P. and Woods, A. (1982). Collecting methods and the adequacy and attempted fauna surveys, with reference to the Diptera. Field Studies 5: 607-621.

Economopoulos, A. P. (1989). Use of traps based on colour and or shape. *In* Robinson, A. S. and Hooper, G. (eds.) World Crop Pests, Fruit Flies, their biology, natural enemies and control 3B: 315-328. Elsevier Sci. Publs. B. V.: Amsterdam.

Ferro, D. N. and Sychak, G. J. (1980). Assessment of visual traps for monitoring the asparagus miner, *Ophiomyia simplex*. Ent. exp. appl. 28: 177-182.

Greany, P. D., Agee, H. R., Burditt, A. K. and Chambers, D. L. (1977). Field studies on colour preferences of Caribbean fruit fly, *Anastrepha suspensa* (Diptera: Tephritidae). Ent. exp. appl. 21: 63-70.

Kennedy, J. S., Booth, C. O. and Kershaw, W. J. S. (1961). Host finding of aphids in the field. III. Visual attraction. Ann. appl. Biol. 49: 1-21.

Kirk, W. D. J. (1984). Ecologically selective coloured traps. Ecol. Ent. 9: 35-41.

Kring, J. B., (1967). Alighting aphids on coloured cards in a flight chamber. J. econ. Ent. 60: 1207-1210.

Mensah, R. K. and Madden, J. L. (1992). Field studies on colour preferences of *Ctenarytaina thysanura* in Tasmanian boronia farms. Ent. exp. appl. 64: 111-115.

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

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 Boller, E. F. (1971). Response of european cherry fruit flies to coloured rectangles. J. econ. Ent. 64: 1444-1447.

Prokopy, R. J. and Owens, E. D. (1983). Visual detection of plants by herbivorous insects. Ann. Rev. Ent. 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. Ent. 15: 331-334.

Room, P. M. and Wardhaugh, K. G. (1979). 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.

Weseloh, R. M. (1981). Relationship between coloured sticky panel catches and reproductive behaviour of forest tachinid parasitoids. Environ. Ent. 10: 131-135.

Wilde, W. H. A. (1962). Bionomics of the pear psylla, *Psylla pyricola* in pear orchards of Kootenay Valley of British Columbia. Can. Ent. 94: 845-849.

(Accepted 15 May 1997)