Influence of Trap Colour on the Capture of Codling Moth (Lepidoptera: Tortricidae), Honeybees, and Non-target Flies

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ABSTRACT

Studies were conducted to evaluate the influence of trap colour on the captures of honeybees, *Apis mellifera* L., codling moth, *Cydia pomonella* L., and non target muscoid flies in sticky delta traps. Traps varied widely in their spectral reflectance. The unpainted white and the painted white and cream traps had the highest reflectance. The painted green trap had the lowest total reflectance. The green, orange, and red traps had low reflectance at wavelengths < 560 nm. Red and green painted traps consistently caught the fewest honeybees, while the unpainted white trap caught the most. Red painted traps caught the greatest number of flies. Significantly more codling moths were caught in green and orange versus the unpainted white traps. In a later experiment, painted green traps caught more codling moths than unpainted white traps.

Key words: Colour, traps, apple, codling moth, honeybees, muscoid flies

INTRODUCTION

Optimizing trap design is vital in developing a useful monitoring system for codling moth, *Cydia pomonella* L. (Knight and Christianson 1999). The effectiveness of a variety of sticky and non-sticky trap types have been reported (Knodel and Agnello 1990, Vincent *et al*. 1990), but until recently, a sticky cardboard white or cream color wing trap has been the standard for monitoring codling moth in the western United States (Riedl *et al*. 1986). Knight *et al*. (2002), however, found that either a delta or diamond-shaped trap was more effective than the standard wing trap in laboratory flight tunnel and in field trials. We believe the delta-shaped trap has now become the most widely used trap for monitoring codling moth in Washington State. Unfortunately, early in the season the delta-shaped trap constructed from white corrugated plastic consistently catches non-target flies and honeybees, *Apis mellifera* L. Trap contamination by flies and honeybees requires that the trap's sticky liner be replaced more frequently and thus adds to the costs of monitoring codling moth.

Colour is an important factor influencing the foraging behaviour of honeybees (von Frisch 1967). Honeybees can differentiate six colour ranges between 300 and 650 nm, i.e. ultraviolet to yellow light (Burkhardt 1964). Variable degrees of contamination of monitoring traps by honeybees and bumblebees *Bombus spp*., due to differences in trap colour have been reported (Hamilton *et al.* 1971, Gross and Carpenter 1991, Meagher 2001). In general, white and yellow traps are attractive and green traps are unattractive to Apoidea species due to their differences in spectral reflectance between 380 and 550 nm (Mitchell *et al.* 1989).

The influence of trap colour on the capture of some noctuid pests in sex pheromone-baited traps has been well studied (McLaughlin *et al.* 1975, Mitchell *et al.* 1989). However, the importance of the visual stimuli provided by traps in these two studies of night-flying moths contrasted sharply. McLaughlin *et al.* (1975) found that traps with low spectral reflectance were more effective in capturing *Trichoplusia ni* (Hübner) and *Pseudoplusia includens* (Walker), while Mitchell *et al.* (1989) found that such traps were less effective with *Anticarsia gemmatalis* Hübner and *Spodoptera frugiperda* (J.E. Smith). Trap colour has not previously been reported to be a specific factor influencing the capture of codling moth. The objective of our study was to evaluate the influence of trap colour on the attractiveness and selectivity of delta-shaped traps for codling moth, honeybees, and non-target flies.

MATERIALS AND METHODS

Description of traps. White delta traps (Suterra, Bend, OR) were left unpainted or painted with one of five high gloss paints (Krylon , Cleveland, OH): Spring Grass green #2327, Pumpkin orange gloss #2411, Banner Red Gloss #2108, Ivory gloss #1504, and Gloss white #1501. The three darker colours were characterized based on value, chroma, and hue (Munsell Book of Colour 1976): green (4, 8, 5G), red (4, 14, 5R), and orange (6, 14, 2.5YR).

Spectral Reflectance. Trap samples (100 cm^2) were scanned with a Perkin-Elmer Lambda-9/19 spectrophotometer (Wellesley, MA) by Avian Technologies (Wilmington, OH). Trap surfaces were scanned at wavelengths from 360 to 830 nm with a monochromatic slit width set at 2 nm and operated at a scan rate of 120 nm / min.

Experiments 1 and 2. Two experiments were conducted in a 5-year-old 'Red Delicious' apple orchard, *Malus domestica* (Borkh), (mean (SE) tree height = 2.2 (0.2) m) situated 15 km east of Moxee, Washington (46°40'N, 120°05'W) at the U.S.D.A. Experimental Farm during 2003. This orchard was situated 0.6 km east of a large dairy farm. Bloom in the apple blocks at the farm occurred from 25 April – 15 May. In the first study (24 – 28 April) delta traps were not baited with a sex pheromone lure. Traps in the second study (5 – 12 May) were baited with the Biolure 10X codling moth lure (Suterra, Bend, OR). Ten traps of each colour were placed in a completely randomized design in each experiment. Unsexed, laboratory-reared codling moth adults (n = 5,000) were released into the orchard prior to the start of experiment 2 only.

Experiment 3. A third experiment was conducted to compare the attractiveness of the unpainted white and the green-painted delta traps for codling moth. This study was conducted in a 10-ha 30-year-old mixed block of 'Red Delicious' and 'Golden Delicious' situated 5 km north of Moxee, Washington (46°33'N, 120°23'W). Mean (SE) tree height in this orchard was 4.3 (0.2) m. Six traps of each colour were placed in a completely randomized design, checked every 2 to 4 d, and re-randomized. Six replicates of this experiment were conducted from 9 – 26 September. Unsexed, laboratory-reared codling moth adults (n = 5,000) were released into the orchard prior to the start of the experiment.

In all experiments, the numbers of codling moths, honeybees, and muscoid flies were counted in each trap. The predominant weather patterns during these tests were clear skies with maximum daily temperatures ranging from 20 – 32 °C.

Statistical analyses. Data were transformed with square root (x + 0.01) prior to analysis. Data from experiments 1 and 2 were analyzed with one-way analysis of variance (ANOVA). The September study was analyzed with a repeated measures design (ANOVA) across five dates. Means were separated in significant ANOVA's with Fisher's least significance difference (Analytical Software 2001).

RESULTS

The spectral reflectance pattern of delta traps differed sharply among colours (Fig. 1). The unpainted white and the painted white and cream traps were similar exhibiting > 75% reflectance at all wavelengths > 420 nm (Fig. 1). These traps had identical reflectance in the ultraviolet at 5 – 30%. Green traps had the lowest total reflectance among colours tested with a peak reflectance (ca. 20%) at 520 nm and < 10% reflectance at wavelengths <

480 nm and > 570 nm (until 810 nm). The reflectance of the orange and red traps increased rapidly at 560 nm and 600 nm and reached a plateau of ca. 55% at 620 nm and 640 nm, respectively.

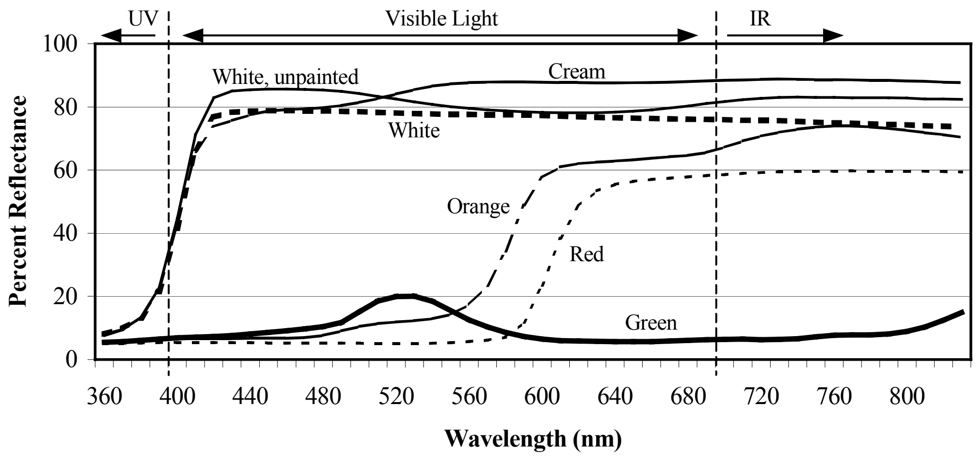

Figure 1. Percent reflectance from 360 to 830 nm of six corrugated plastic delta-shaped traps either left unpainted (white) or painted cream, red, green or orange.

Significant differences were found in the mean capture of codling moths, honeybees and flies in all but one delta trap comparison in experiments 1 and 2 (Table 1). The fewest honeybees were caught in the red, orange, and green painted delta traps in experiment 1 and in the painted white, cream, red, and green traps in experiment 2. The painted white and cream traps caught significantly fewer honeybees than the unpainted white trap in experiment 1. All but the unpainted white trap caught significantly fewer honeybees than the orange trap in experiment 2.

The vast majority of flies caught during experiments 1 and 2 were the lesser stable fly, *Muscina stabulans* (Fallen), and the little house fly, *Fannia canicularis* L., likely immigrating from the nearby dairy. Red traps caught significantly more flies than all other colours, and orange traps caught significantly more flies than the cream, white, and

Table 1.
The influence of trap colour on the capture of codling moths, honeybees, and flies in delta traps placed in an apple orchard in experiments 1 (28 April) and 2 (12 May).

	Mean (SE) catch per trap				
Painted trap colour	Codling moth	Honeybees		Flies	
	Exp. 2	Exp. 1	Exp. 2	Exp. 1	Exp. 2
Unpainted, white	7.7 (2.5)c	9.5 (1.2)a	4.4 (0.7)a	0.1 (0.1)c	4.9 (1.0)
White	6.0 (1.6)c	2.3 (0.5)b	0.6 (0.2)c	0.0 (0.0)c	11.3 (4.5)
Cream	14.2 (3.6)bc	2.8 (0.4)b	0.9 (0.5)c	0.3 (0.2)c	5.9 (2.6)
Red	14.8 (3.5)abc	0.0 (0.0)c	0.0 (0.0)c	3.7 (0.7)a	23.3 (5.2)
Orange	29.8 (7.8)ab	0.3 (0.2)c	2.4 (0.7)b	1.8 (0.6)b	10.1 (1.6)
Green	34.9 (11.5)a	0.1 (0.1)c	0.0 (0.0)c	1.0 (0.3)bc	8.4 (1.8)
Statistical analysis	$F = 4.24$	$F = 42.11$	$F = 15.69$	$F = 12.58$	$F = 1.26$
df = 5, 54	$P < 0.01$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P = 0.30$

Means within the same column followed by the same letter are not significantly different at $P < 0.05$ (LSD test).

unpainted traps in experiment 1. Fly captures were much higher and more variable during experiment 2, though no differences were significant (Table 1).

No codling moths were caught in the unbaited traps in experiment 1. Significant differences in the catch of codling moths in experiment 2 occurred among trap colours (Table 1). The lowest mean catches were in the unpainted and white traps but these were not significantly different from the cream and red traps. Catch was significantly higher in the orange versus the white or unpainted traps. Mean moth catch in the green traps was significantly greater than in the unpainted, white or cream traps.

The green delta trap caught significantly more codling moths than the unpainted white trap (F = 42.64; df = 1, 10; P < 0.001); mean (SE) = 13.7 (2.4) versus 6.3 (1.2), respectively) in experiment 3. No honeybees were caught in any trap in experiment 3, and the capture of flies was low, averaging < 0.2 per trap, so data were not analyzed.

DISCUSSION

Visual cues are known to be an important factor affecting the close range orientation of male codling moth to females or synthetic lures (Castrovillo and Cardé 1980). Visual cues may also play a role in oviposition behaviour, which occurs from late afternoon to dusk (Riedl and Loher 1980). The role of colour on the orientation of male codling moths at dusk to discrete sex pheromone sources is unknown. The correlation of our traps' reflectance data and their relative capture of codling moth suggest that traps with low reflectance at wavelengths < 560 nm may catch more moths than the standard white and cream traps. A spectral analysis of the sensitivity of codling moth's compound eye may allow us to make a significant improvement in the design of a more effective monitoring trap.

It is not clear from the literature whether visual detection of a trap by a moth should increase or decrease the number of individuals captured in a sex pheromone-baited trap. For example, the compound eyes of some noctuid moths have been shown to have a bimodal sensitivity to light with peaks in the UV (350 – 370 nm) and green (500 – 575 nm) regions (Agee 1973, Mitchell *et al.* 1989). Yet, other noctuid species respond more strongly to traps emitting low spectral reflectance in these regions (McLaughlin *et al.* 1975).

The significant differences found in the effectiveness of delta traps of different colours in the capture of codling moths suggest that the potential influence of colour in previous codling moth trapping studies should be reexamined. Most of the paper and plastic traps used to monitor codling moth have been cream or white (Riedl *et al.* 1986). No studies with codling moth have compared traps of similar geometry that differ only in colour. Plastic bucket traps with a green flat top and a white cylindrical bottom were found to have higher seasonal catches of codling moth than paper, cream colour wing traps (Vincent *et al.* 1990). Knodel and Agnello (1990) found that a small, orange delta trap caught nearly twice as many codling moths as either the cream colour or white wing traps in their study. Conversely, they also reported that the all-green bucket trap caught fewer moths than any other design including two designs of a green and white bucket trap. However, these differences among the bucket traps could have been due to the significant differences in the size and geometry of the various traps' openings.

Green delta traps in our studies appeared to be the most selective and attractive colour for monitoring codling moth. Painted or unpainted white traps and cream traps all caught honeybees. We did not determine if red, orange or green traps differ in their attractiveness for codling moth. However, green and red appeared to catch somewhat fewer honeybees than orange traps, and both green and orange caught fewer flies than red traps.

The benefit derived by excluding honeybees from codling moth traps could be cancelled by an increase in the trap's captures of large flies in some orchards. The capture of flies varied widely among our experiments due to differences in location and seasonality. The highest numbers of flies were caught in experiment 2 in an orchard situated near a dairy, and only negligible captures of flies occurred in experiment 3 in an orchard surrounded by other orchards. The higher counts of flies in experiment 2 versus experiment 1 were likely due to an increase in the mean maximum temperatures (> 3 ^{o}C) that occurred from late April to early May.

Visual stimuli are well known to be important factors affecting the behaviour of muscoid flies (McCann and Arnett 1972). The influence of colour on the level of attractiveness to the stable fly, *Stomoxys calcitrans* L., has been shown to be red > green > yellow > white (Muniz and Hecht 1968). The behavioural responses of *S. calcitrans*; the face fly, *Musca autumnalis* De Geer; and the horn fly, *Haematobia irritans* L., are all greatest to surfaces with < 20% reflectance in the range from 350 to 450 nm (Agee and Patterson 1983). Similarly, in our study the low captures of muscoid flies in the white and cream traps may be associated with their high mean reflectance (> 50%) in the range from 360 – 450 nm (Fig. 1). Thus it might be possible to reduce the capture of muscoid flies in the green, red, and orange traps if a UV reflector was added to the trap's surface.

The congregation of muscoid flies to surfaces can also be their response to regulate their body temperature (Bushman and Patterson 1981). Flies may congregate on warmer surfaces during cool mornings or afternoons (Agee and Patterson 1983). The interior surface of the darker delta traps during the summer can be 2 – 4% warmer than white traps (unpublished data). Further research detailing the influence of temperature and other climatic factors on the capture of muscoid flies in delta traps may allow us to further improve the selectivity of this trap in monitoring codling moth. Further studies on the visual sensitivity of codling moth and its associated behaviour may allow us to develop a trap that is both more attractive for codling moth and less attractive to muscoid flies.

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