Response of Tortricid Moths and Non-Target Insects to Pheromone Trap Color in Commercial Apple Orchards[1]

Clayton T. Myers,[2] Grzegorz Krawczyk,[3] and Arthur M. Agnello[4]

USDA-ARS, Appalachian Fruit Research Station, Kearneysville, West Virginia 25430 USA

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Abstract Pheromone traps are a widely-used tool for monitoring pest activity in commercial apple orchards. Studies were conducted to evaluate delta-style traps painted with different colors (orange, red, yellow, green, blue, and white) for capture of obliquebanded leafroller, *Choristoneura rosaceana* (Harris), and oriental fruit moth, *Grapholita molesta* (Busck), as well as nontarget muscoid flies (Diptera: Muscidae) and honeybees, *Apis mellifera* L. An additional study evaluated plastic, four-sided LepTrap® traps of various colors in comparison with a standard delta trap for capture of obliquebanded leafroller, oriental fruit moth, tufted apple bud moth (*Platynota idaeusalis* (Walker)), and codling moth (*Cydia pomonella* L.). Capture of obliquebanded leafroller and oriental fruit moth was not significantly affected by trap color. Capture of nontarget flies and honeybees tended to be higher in blue and white (both painted and unpainted) delta-style traps in New York apple orchards, although there was some variability in this response by orchard site. There were no differences in capture of 4 pest species in Pennsylvania between colored, plastic LepTrap® traps and standard unpainted white delta-style traps. Given the observed differences in nontarget capture and the improved efficiencies of finding traps placed within tree canopies, we recommend using yellow, red, or orange delta traps for monitoring of obliquebanded leafroller, oriental fruit moth, and tufted apple bud moth in apple production areas in the eastern United States.

Key Words pheromone trap, color, apple, obliquebanded leafroller, oriental fruit moth, tufted apple bud moth, codling moth, honeybees, muscoid flies

Sex pheromone traps are an important tool for monitoring activity of tortricid pest species in commercial apple orchards, and interpretation of data derived from these traps is important for making pest management decisions. Understanding factors that may affect interpretation of data is important in efforts to design better traps and optimize efficiency of monitoring efforts. Trap designs with low capture efficiency pose the risk of underestimation of pest pressure and, thus, unexpected pest damage. Conversely, designs that are overly attractive to insects can cause inefficiency of monitoring efforts due to saturation by nontarget insects (such as bees, wasps, flies, etc.) or even the pest species being monitored (Brown 1984, Knight 2001).

Whereas prior work has been published on the effect of trap color on capture of codling moth, *Cydia pomonella* L. (Knight and Miliczky 2003, Knight and Fisher 2006),

[1]Received 25 March 2008; accepted for publication 16 May 2008.

[2]Address inquiries (email: cmyers20@hotmail.com).
[3]The Pennsylvania State University, Fruit Research and Extension Center, Biglerville, PA 17307.
[4]Cornell University, New York State Agricultural Experiment Station, Geneva, NY 14456.

no such studies have been conducted to evaluate color effects on capture of oriental fruit moth, *Grapholita molesta* (Busck), obliquebanded leafroller, *Choristoneura rosaceana* (Harris), or tufted apple bud moth, *Platynota idaeusalis* (Walker). All of these are pests of significant economic importance in apple-producing regions of eastern North America and are intensively monitored with sex pheromone traps of various designs as part of established integrated management protocols in this region (Anonymous 2004, 2006, Agnello et al. 2007).

Trap color may also impact capture of nontarget insect species, which can contaminate traps intended to capture a specific pest species. Such contamination results in increased time for trap maintenance and increased costs associated with periodic replacement of soiled trap bottoms. Muscoid flies (Diptera: Muscidae) are frequently captured in pheromone traps at various times of the growing season. Additionally, capture of nontarget Hymenoptera, such as bumble bees, *Bombus* spp., and honeybees, *Apis mellifera* L., is also common in apple orchards. Besides the problem of trap contamination, inordinate capture of beneficial bees may detract from pollination or reduce populations of commercial honeybee colonies that are of significant economic importance. Ideally, a sex pheromone trap would be sufficiently attractive to the pest species of interest while remaining unattractive to nontarget species. Trap color effects have been described on capture of bees in fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Gross and Carpenter 1991, Meagher 2001), and delta-shaped codling moth traps (Knight and Miliczky 2003).

Herein we report studies that were conducted to evaluate the impact of color on the pheromone trap capture of obliquebanded leafroller and oriental fruit moth, as well as nontarget flies and bees. Additionally, another study was designed to evaluate various colors of a novel plastic trap design in comparison with a standard white (unpainted) delta-style pheromone trap for capture of oriental fruit moth, codling moth, obliquebanded leafroller, and tufted apple bud moth.

Materials and Methods

Delta-style trap color studies. Two experiments were conducted in commercial apple, *Malus domestica* (Borkh.), orchards in Wayne Co. NY, and Adams Co. PA. All blocks received standard management inputs, including insecticide treatments at the discretion of participating growers. Four orchard blocks in New York (block sizes 3-5 ha each) were used for evaluation of traps for obliquebanded leafroller capture and capture of nontarget honeybees and muscoid flies from 25 June through 28 August 2005. Two orchard blocks in Pennsylvania (~10 plus ha each) were used for evaluation of oriental fruit moth from 21 July through 25 August 2005. White BioLure® delta-style pheromone traps (Suterra, Bend, OR) were spray-painted (Krylon®, Cleveland, OH) on 15 June 2005 with 1 of 6 colors: pumpkin orange gloss #2411, banner red gloss #2108, sun yellow gloss #1206, spring grass green #2327, true blue gloss #1910, and glossy white #1501. All colors except white were characterized by value, chroma, and hue via the Munsell system: orange (6, 14, 2.5YR), red (4, 14, 5R), yellow (8, 12, 5Y), green (4, 8, 5G), and blue (4, 10, 2.5PB). All colors except blue are the same as those evaluated previously by Knight and Miliczky (2003) for codling moth capture.

Traps were baited with standard commercial obliquebanded leafroller or oriental fruit moth BioLure® pheromone lures (Suterra Bend, OR). Twenty-one traps per block (3 of each color plus 3 unpainted control traps) were deployed in a randomized complete block design. Trap trees and rows were marked with colored flagging to expedite finding traps in later weeks. Trap bottoms were cleaned (or changed if total insect accumulation exceeded 50 insects) twice weekly, and pheromone lures were changed every 4 wks. Traps were cleaned and rotated twice weekly after recording capture of obliquebanded leafroller, honeybees, and muscoid flies at the New York sites. Traps were placed on 16 June and maintained through 22 August. At the Pennsylvania sites, trap maintenance and rotation was the same, but only oriental fruit moth capture was recorded. Traps were placed on 21 July and maintained through 25 August.

For obliquebanded leafroller, moth captures were totaled for each brood (brood one: 20 June-19 July, brood two: 8-25 August). Total first brood capture, total second brood capture, and total seasonal capture of obliquebanded leafroller, along with total seasonal captures of honeybees and muscoid flies were each analyzed using a two-way factorial (site, color, site x color) analysis of variance of ln-transformed data ($P < 0.05$) (SAS Institute 2002). Mean total captures of flies and bees also were analyzed independently for each orchard site, by color, using a one-way analysis of variance of the same data. Moth counts were ln-transformed to stabilize the variances. Means were separated using Fisher's protected LSD test ($P < 0.05$). For oriental fruit moth, total seasonal capture was analyzed using a two-way factorial (site, color, site x color) analysis of variance, using ln-transformed data ($P < 0.05$).

Plastic LepTrap® traps evaluation. During the 2005 season, 4-sided plastic LepTrap® traps (Plato Industries, Houston, TX, USA) (Fig. 1) with removable sticky floors were evaluated in a mature, mixed cultivar apple orchard (~12 ha). Moth capture of 4 LepTrap trap colors—blue, green, red and white—was compared with capture in standard, unpainted plastic delta trap for codling moth, obliquebanded leafroller,

Fig. 1. Blue plastic LepTrap® trap placed in an apple tree during bloom. Sticky trap bottom is not in place

oriental fruit moth and tufted apple bud moth. Munsell color values for the colored traps were as follows: blue (4, 12, 7.5PB), green (7, 10, 7.5GY), and red (5, 12, 2.5R). Each trap was baited with standard septa lure specific for each species (Suterra Bend, OR). Lures and sticky floors in all traps were exchanged every 4 wks unless more frequent exchange was warranted due to the external conditions. The apple orchard was divided into 3 similar size blocks (replicates), and a single trap of each kind was used per block (5 different colored traps for each species distributed among 5 trapping stations within each block, each with a single trap for each species). Trap colors for various species within each station were assigned randomly. All stations and traps within each station were rotated on a weekly basis throughout the season. Trap capture for each species was totaled for the season and analyzed independently using one-way analysis of variance, using ln-transformed data ($P < 0.05$).

Results

Delta-trap color studies. Brood One obliquebanded leafroller mean trap capture in Wayne Co. NY, did not vary significantly by color ($F = 1.24$; df = 6, 83; $P = 0.3014$) or site ($F = 0.35$; df = 3, 83; $P = 0.7869$), and there was no site x color interaction ($F = 0.42$; df = 18, 83; $P = 0.9770$). Brood Two mean captures also did not vary by color ($F = 0.58$; df = 6, 83; $P = 0.7457$) but varied significantly by site ($F = 21.81$; df = 3, 83; $P < 0.0001$), with no site x color interaction ($F = 1.18$; df = 18, 83; $P = 0.3068$). Seasonal total obliquebanded leafroller trap capture did not vary by color ($F = 0.72$; df = 6, 83; $P = 0.6387$), but varied by site ($F = 5.39$; df = 3, 83; $P = 0.0025$) with no significant interaction ($F = 0.40$; df = 18, 83; $P = 0.9817$). Seasonal total obliquebanded leafroller capture averaged ~15-40 moths per trap, depending on site.

Mean seasonal total capture of muscoid flies varied significantly by color ($F = 58.00$; df = 6, 83; $P < 0.0001$) and site ($F = 53.17$; df = 3, 83; $P < 0.0001$) with a significant site x color interaction ($F = 2.92$; df = 18, 83; $P = 0.0011$). Fly capture varied significantly by color at all sites (Site 1: $F = 4.87$; df = 6, 20; $P = 0.007$; Site 2: $F = 19.59$; df = 6, 20; $P < 0.001$; Site 3: $F = 26.92$; df = 6, 20; $P < 0.001$; Site 4: $F = 20.76$; df = 6, 20; $P < 0.001$) (Table 1). Blue and unpainted white traps captured significantly more flies than red, green, orange, or yellow traps. Painted white traps also had higher fly captures than red, green, orange, or yellow traps at 3 of the 4 sites. At one site (3), unpainted white traps captured more flies than painted white traps (Table 1).

Mean seasonal total capture of honeybees varied significantly by color ($F = 38.20$; df = 6, 83; $P < 0.0001$) and site ($F = 12.19$; df = 3, 83; $P < 0.0001$), with a significant site x color interaction ($F = 2.63$; df = 18, 83; $P = 0.0030$). Bee capture varied significantly by color at all sites (Site 1: $F = 3.10$; df = 6, 20; $P = 0.038$; Site 2: $F = 19.53$; df = 6, 20; $P < 0.001$; Site 3: $F = 12.87$; df = 6, 20; $P < 0.001$; Site 4: $F = 4.22$; df = 6, 20; $P = 0.012$) (Table 2). White-colored traps (either painted or unpainted) captured significantly more bees than red, green, orange, or yellow traps at all sites. Meanwhile, blue traps captured more honeybees than red, green, orange, or yellow traps at 2 of 4 sites (Table 2).

Total oriental fruit moth trap capture from 21 July–25 August 2005 in Adams Co. PA, did not vary by trap color ($F = 0.43$; df = 5, 35; $P = 0.8208$) but varied significantly by site ($F = 11.04$; df = 1, 35; $P = 0.0028$). There was no significant color x site interaction ($F = 0.31$, df = 5, 35; $P = 0.9009$). Seasonal total obliquebanded leafroller capture averaged ~40-100 moths per trap, depending on site.

Plastic LepTrap® traps evaluation. There was no significant variation among colored plastic LepTrap traps and standard delta traps for seasonal capture of oriental

Table 1. Mean (SEM) total seasonal capture of muscoid flies captured in delta-style pheromone traps baited with obliquebanded leafroller lures at 4 sites in Wayne Co., NY, 2005

Site	Trap Color	n*	Mean flies per trap **		
1	Red	3	0.00	(0.00)	a
	Yellow	3	0.67	(0.33)	a
	Green	3	0.67	(0.33)	a
	Orange	3	1.33	(0.88)	ab
	White (painted)	3	2.33	(0.88)	ab
	White (unpainted)	3	5.33	(1.20)	b
	Blue	3	5.33	(2.60)	b
2	Red	3	1.67	(0.33)	a
	Green	3	2.33	(1.20)	a
	Orange	3	5.00	(0.58)	ab
	Yellow	3	13.00	(6.35)	b
	White (painted)	3	78.67	(13.86)	c
	Blue	3	81.00	(2.65)	c
	White (unpainted)	3	108.00	(44.86)	c
3	Red	3	2.67	(0.33)	a
	Orange	3	3.33	(0.88)	a
	Green	3	3.33	(0.88)	a
	Yellow	3	3.67	(0.88)	a
	White (painted)	3	12.67	(6.17)	b
	Blue	3	26.33	(4.91)	bc
	White (unpainted)	3	40.00	(4.93)	c
4	Orange	3	0.67	(0.33)	a
	Green	3	1.00	(0.00)	a
	Red	3	2.33	(0.33)	a
	Yellow	3	3.00	(1.00)	a
	Blue	3	19.67	(9.94)	b
	White (painted)	3	21.67	(2.60)	b
	White (unpainted)	3	24.33	(6.74)	b

* Number of trap replicates per site for each color.

** Means in each column and within the same site followed by the same letter are not significantly different, Fisher's LSD ($P < 0.05$).

Table 2. Mean (SEM) total seasonal capture honeybees captured in delta-style pheromone traps baited with obliquebanded leafroller lures at 4 sites in Wayne Co., NY, 2005

Site	Trap Color	n*	Mean bees per trap **		
1	Red	3	0.00	(0.00)	a
	Yellow	3	0.00	(0.00)	a
	Green	3	0.00	(0.00)	a
	Orange	3	0.33	(0.33)	ab
	Blue	3	1.33	(0.88)	abc
	White (unpainted)	3	2.33	(0.67)	bc
	White (painted)	3	3.33	(1.76)	c
2	Yellow	3	0.00	(0.00)	a
	Green	3	0.00	(0.00)	a
	Orange	3	0.33	(0.33)	a
	Red	3	0.33	(0.33)	a
	Blue	3	10.67	(2.40)	b
	White (painted)	3	13.67	(3.38)	b
	White (unpainted)	3	18.67	(5.61)	b
3	Red	3	0.00	(0.00)	a
	Green	3	0.33	(0.33)	a
	Orange	3	0.33	(0.33)	a
	Yellow	3	0.67	(0.33)	a
	White (painted)	3	4.00	(1.00)	b
	White (unpainted)	3	5.33	(0.33)	b
	Blue	3	5.33	(1.76)	b
4	Orange	3	0.00	(0.00)	a
	Red	3	0.00	(0.00)	a
	Yellow	3	0.00	(0.00)	a
	Green	3	0.33	(0.33)	a
	Blue	3	1.67	(0.88)	ab
	White (painted)	3	1.67	(0.88)	ab
	White (unpainted)	3	4.67	(1.86)	b

* Number of trap replicates per site for each color.

** Means in each column and within the same site followed by the same letter are not significantly different, Fisher's LSD ($P < 0.05$).

fruit moth ($F = 1.96$; df = 4, 14; $P = 0.1766$), codling moth ($F = 0.34$; df = 4, 14; $P = 0.8451$), tufted apple bud moth ($F = 0.56$; df = 4, 14; $P = 0.6969$), or obliquebanded leafroller ($F = 0.14$; df = 4, 14; $P = 0.9618$) in 2005 in Adams Co., PA.

Discussion

These studies are the first reports on the effects of pheromone trap color on capture of obliquebanded leafroller, oriental fruit moth, and tufted apple bud moth. Most prior published studies in either the laboratory or the field have mainly examined trap geometry (Knight et al. 2002, Krawczyk et al. 1998, 2001) or the attractiveness of different pheromone load rates (Knight 2002) for their effects on trap efficacy. Whereas color variations are sometimes inherent in different trap designs, only 2 prior studies have investigated the influence of different colors on pheromone trap capture of codling moth using traps of identical geometry and design (Knight and Miliczky 2003, Knight and Fisher 2006). They reported that codling moth capture was higher in green and orange delta-style traps when compared with standard unpainted or painted white delta-style traps.

Contrary to those results with capture of codling moth, our data indicate no color-associated difference for capture of either obliquebanded leafroller or oriental fruit moth. Capture of codling moth and tufted apple bud moth was unaffected by different colors of plastic Plato traps in comparison with a standard delta trap; however, that study did not include an orange-colored trap, and all studies were conducted in commercial orchards in the eastern United States. It is of note that Knight and Miliczky (2003) were actually investigating field recapture of laboratory-reared moths that were released into an experimental orchard for 2 of their 3 studies. They used 10X codling moth lures and measured capture over one week. Knight and Fisher (2006) repeated similar studies (using a number of different lures) over multiple weeks during the growing season to confirm enhanced attractiveness of orange traps to wild moth populations in 3 Washington apple orchards. In contrast, our studies measured seasonal capture of wild moths in several commercial orchard sites using only conventional lures (i.e., 1X dose lures) for all pest species, including codling moth.

In contrast to prior findings, we observed higher seasonal capture of flies in white and blue traps than in other colors in New York. Knight and Miliczky (2003) found fly capture was highest in red and orange traps during an early-season study when traps were absent of pheromone lures and proposed that fly capture may be negatively correlated with UV reflectance. A subsequent study with traps baited with pheromone lures showed great variability in fly capture and found no significant effect of trap color. Knight and Miliczky (2003) did not assess capture in yellow or blue traps and did not assess capture beyond the early season. Whereas we did not measure the spectral reflectance of yellow or blue traps, the reflectance of other traps should have been similar to those evaluated by Knight and Miliczky (2003), as identical brands and colors of paint were used. Whereas our study measured seasonal fly capture, by far the majority of these captures occurred over 2 distinct periods during mid-June and mid-to-late July, suggesting that there may be attraction to a specific species or population of flies that is active over a discrete period of time.

Our observations on capture of bees in New York were somewhat consistent with the findings of Knight and Miliczky (2003), who reported highest capture in white unpainted traps. Our data did not indicate significant differences between painted and unpainted white traps. Knight and Miliczky (2003) observed bee capture in orange traps that was higher than capture in white, cream, red, or green traps. We observed no such increased capture in orange traps, but found higher bee capture in blue traps at 2 of 4 sites. Whereas it is interesting that high fly capture seems to be positively associated with higher honeybee capture, there was no evidence suggesting a causal relationship between the two (i.e., flies being attracted to dead bees), as the incidents of high fly capture did not match up temporally with incidents of significant honeybee or moth capture.

Optimally, traps used for efficient pest monitoring should be attractive to pests while being unattractive to nontarget species. For codling moth, the data of Knight and Fisher (2006) indicate that orange traps are preferable to white. Knodel and Agnello (1990) also found increased codling moth capture in orange delta traps of smaller size compared with larger white wing traps. Given our findings, and the limited data present in the literature, we see no evidence to suggest that capture of obliquebanded leafroller, oriental fruit moth, or tufted apple bud moth is affected by trap color in the eastern United States. For these pest species, we recommend choosing trap colors such as yellow, red, or orange, because they are less attractive to nontarget insects such as flies and bees. Whereas green traps were also less attractive to nontarget insects, this color can be problematic for finding the traps placed within the tree canopy.

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