Early Detection and Mass Trapping of *Frankliniella occidentalis*[1] and *Thrips tabaci*[1] in Vegetable Crops

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Abstract. Western flower thrips, *Frankliniella occidentalis* (Pergande), and onion thrips, *Thrips tabaci* Lindeman, are economic pest insects of head lettuce, *Lactuca sativa* L., and dehydrator onions, *Allium cepa* L., in the Imperial Valley, California. Colored sticky traps were evaluated as potential detection and monitoring devices of the two thrip species over a two-month period in 2006. Results showed that blue sticky card traps consistently captured more adult thrips of both species compared to yellow sticky card traps. Numbers of thrips captured on blue sticky traps were positively correlated to numbers captured on yellow sticky traps. Adult thrips were captured in much higher numbers on sticky card traps than recovered from whole plant samples. Significant negative correlations between *F. occidentalis* numbers on plant samples and colored sticky traps suggest that adults left lettuce plants and were attracted to nearby traps. In addition, the numbers of thrips caught on traps relative to estimated plant populations support the hypothesis that mass trapping was significant in the treated area. Spectroradiometric and RGB (red, green, blue) digital image color analysis of the traps in sunlight showed the blue sticky cards reflected considerably more light in the 400-500 nm range (R = 49, G = 187, B = 255) than the yellow sticky cards that reflected more light in the 550-700 nm range (R = 227, G = 234, B = 67). Because blue sticky card traps captured many times more adult thrips than recovered from whole plant samples, blue traps may be more sensitive in detecting early presence of thrips in lettuce and onion fields.

Introduction

Head lettuce, *Lactuca sativa* L., cv. Lighthouse, and dehydrator onions, *Allium cepa* L., cv. white creole, are high-income vegetable crops planted in the Imperial Valley, California. The total production in Imperial County in 2005 was 12,596 and 3,922 ha for lettuce and onions, respectively. Western flower thrips, *Frankliniella occidentalis* (Pergande), and onion thrips, *Thrips tabaci* Lindeman, are economic pest insects that can reduce onion yields by more than 50% in severely infested fields (Coviello and McGriffen 1995). The average annual economic loss to onions in California from both thrip species is estimated at $21 million. Results from 2005 and

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2006 surveys by growers, licensed pest control advisors, cooperative extension personnel and lettuce industry professionals working in Yuma Valley, Arizona, and Imperial Valley, California, revealed that over one-third of the fall lettuce grown was treated for thrips at costs ranging from $91.33 to $103.44 per ha in 2004 and 2005 (Palumbo et al. 2006). Crop losses from thrip infestations on fall lettuce were estimated at about 0.5% (Palumbo et al. 2006). Both thrip species are polyphagous and are tospovirus vectors (Mound 2005, Thrips knowledge base 2006). *F. occidentalis* is also a vector of CSNV (chrysanthemum stem necrosis virus), GRSV (groundnut ringspot virus), INSV (impatiens necrotic spot virus), TCSV (tomato chlorotic spot virus), and TSWV (tomato spotted wilt virus), while *T. tabaci* vectors IYSV (iris yellow spot virus) and TYFRV (tomato yellow fruit ring virus) (Campbell et al. 2006, Sherwood 2005). University of California Integrated Pest Management (UC IPM) Thrips Monitoring Guidelines have been successfully implemented for growers to manage thrips in the field (Coviello et al. 2005). However, early detection tools using traps are needed to avoid costly plant sampling as long as feasible. Previous studies indicated that *F. occidentalis* is attracted to blue color (Matteson and Terry 1992, Chu et al. 2000, Roditakis et al. 2001, Chen et al. 2004, Chu et al. 2006) and *T. tabaci* is attracted to yellow color (Teulon and Brown 1992, Jenser et al. 2001, Al-Ayedh and Al-Doghairi 2004) and blue (Liu and Chu 2004). The objectives of this study were to evaluate the efficacy of blue and yellow sticky card traps for detection of *F. occidentalis* and *T. tabaci* in lettuce and onion fields in the irrigated desert growing areas of the Imperial Valley, California, and to determine relationships between thrips captured on traps and those found using whole plant sampling.

Materials and Methods

The study was conducted in fields of head lettuce, cv. lighthouse, at the University of California Desert Research and Extension Center, Holtville, CA, and dehydrator onion, cv. white creole, at the Imperial Valley Research Center, Brawley, CA. Onions and lettuce in each case were planted in 144-m^2 areas on 3 October and 28 November 2006, respectively. Crops were grown using commercial cultural practices (Meister et al. 2004) with about 75 onions and 6.25 lettuce plants per m^2.

The experiments were randomized complete block designs with twelve replicates of three plots each (36 plots) with each plot being 2 m x 2 m. In each replicate, plants were sampled in one plot while two of the plots had either a 155-cm^2 (10.3 x 7.5 cm) blue (Takitrap®, Oecis Ltd., Kimpton, Hertfordshir, England) or yellow (Olson Products, Medina, OH) trap that was coated with adhesive on both sides. Reflected wavelengths from the colored sticky traps in sunlight were recorded with a USB2000 spectroradiometer using OOIBase32 Version 2.0.2.2 software (Ocean Optics Inc., Dunedin, FL). A solarization-resistant, UV transparent, optical fiber (400 μm) probe with adjustable collimating lens was held perpendicular to the surface to capture the spectral reflection. Reflectance intensity readings from the near UV through the visible wavelengths (300-850 nm) were automatically scanned using an integration time of 5 ms. In addition, the same traps were photographed with a Nikon Coolpix® 2100 digital camera to obtain JPEG images that were analyzed for red, green, and blue component intensities (RGB) with software described by Byers (2006).

Each trap was secured on top of a bamboo stake (1.5 x 75 cm) driven into the ground in the center of a plot. Traps were placed 50 cm above the seed bed within lettuce or onion. Traps were placed for one week in the fields prior to retrieval and then placed in re-closable sandwich bags (16.5 x 14.9 cm, Amerfood Trading Co. Los

Angeles, CA). Immediately following trap retrievals, five whole plants were picked at random within each replicated block and bagged in labeled disposable plastic bags described above. Traps and plant samples were taken to the laboratory and stored in a refrigerator until analysis. *F. occidentalis* and *T. tabaci* adults and larvae were identified and counted under a dissecting binocular microscope. The studies were conducted in 2006 from 7 February to 11 April for lettuce, and from 6 February to 4 April for onions. Whole plant sampling for onions followed the established University of California Pest Management Guidelines for thrips sampling on onion crops (Coviello et al. 2005). University of California Pest Management Guidelines have not been established for thrips sampling on lettuce crops (Natwick et al. 2002).

For each thrip species and crop, thrip numbers on plant samples and traps were analyzed for significant differences by ANOVA and Tukey HSD methods (Statistica 5.1, StatSoft Inc., Tulsa, Oklahoma) in each crop. Pair-wise correlation matrices were performed on data from 12 replicated blocks of eight sample dates (N = 96) to assess relationships between numbers of adults and larvae of each thrip species on plants, adults on plants and on either blue or yellow traps, and adults on blue versus yellow traps for each crop (Statistica). Due to multiple comparisons of two thrip species caught on two colors of trap in two crops, the significance level was set at 0.05/n, where n = 8. To better understand the significance of negative correlations, randomly generated sets of *plant* and *trap* data were tested for correlations (Sokal and Rohlf 1995) with and without various numbers of data pairs with a portion subtracted from the *plant* and another proportion added to the corresponding *trap* (BASIC code available from authors).

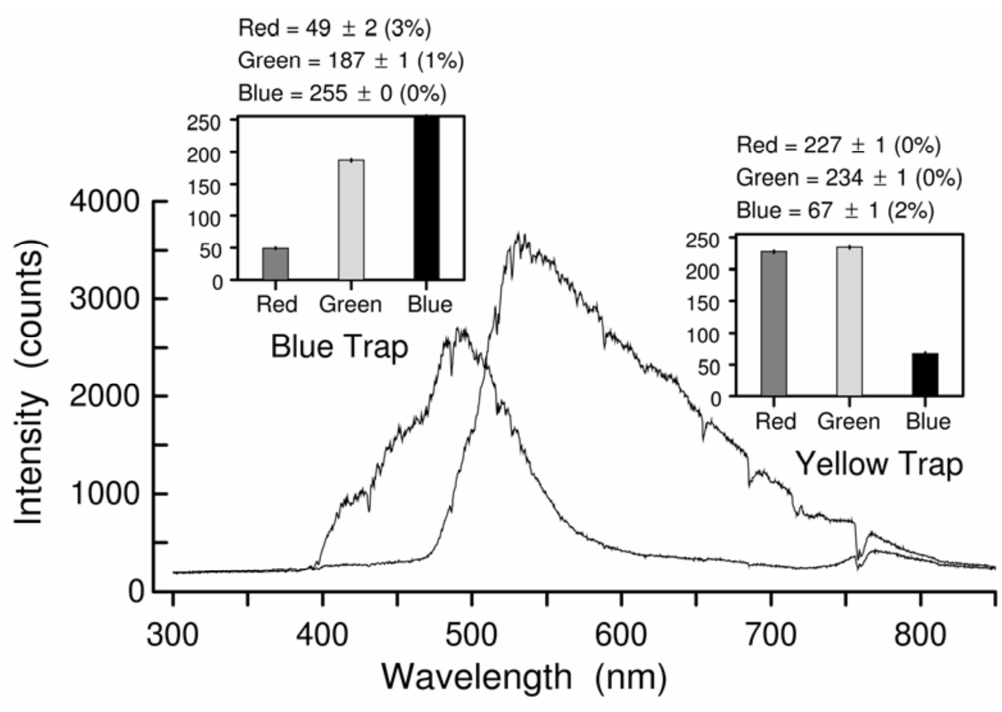

FIG. 1. Overlaid spectroradiograms of sunlight reflected off the blue and yellow sticky traps as indicated (22 November 2006 at 11:00 AM, Maricopa, Arizona). Bar graphs are red, green, and blue RGB values (mean ± SD, CV%, N = 2016 pixels) of images of the traps taken by a Nikon 2100 digital camera at the same time as the spectroradiograms.

Results and Discussion

The reflected wavelengths of the blue trap are more intense in the near ultraviolet and blue region than the yellow trap (Fig. 1). The yellow trap reflected more light in the yellow to red regions of the spectrum as expected. The mean RGB values for each trap color (Fig. 1) show little variation among pixels due to the uniformity (low ± SD and CV%) of the colored areas. Most insects including those in the orders Odonata, Orthoptera, Heteroptera, and the advanced holometabolous orders have ultraviolet receptors (maximal absorption 345-360 nm), blue receptors (400-450 nm), and green receptors (515-540 nm) (Menzel and Blakers 1976, Laughlin 1976, Chittka 1997, Kevan et al. 2001, Briscoe et al. 2003, Byers 2006). *F. occidentalis*, in particular, has been shown to have good sensitivity to UV and green-yellow (540 nm) light as recorded by electroretinograms (Matteson and Terry 1992). Thus, it is likely that individuals of thrip species can discriminate both blue and yellow trap colors.

More adult *F. occidentalis* were captured on blue traps compared with yellow traps in lettuce (Table 1). A few *F. occidentalis* larvae were captured on blue and yellow traps but numbers were not tabulated. The average number of adult *F. occidentalis* captured on the blue trap per week (579) was 26 times the average number recovered from five whole plant samples. The blue traps usually caught

Table 1. Mean numbers (± SE) of *Frankliniella occidentalis* and T. *tabaci* on plant samples compared with mean weekly catches on blue and yellow sticky card traps in lettuce and onion fields, Imperial Valley, California, 7 February to 11 April 2006 (lettuce) and 6 February to 6 April (onion).

Treatment	Plant sample	Yellow sticky card	Blue sticky card
Lettuce			
F. occidentalis			
Adults[a]	22.44 ± 7.34a	421.07 ± 80.74b	578.57 ± 90.79c
Larvae	11.93 ± 4.57	0.14 ± 0.14	0.02 ± 0.02
T. tabaci			
Adults	0.56 ± 0.16a	2.52 ± 1.25a	5.60 ± 2.08b
Larvae	0.38 ± 0.21	0	0
Onion			
F. occidentalis			
Adults	10.07 ± 2.53a	385.17 ± 68.53b	614.34 ± 115.62c
Larvae	8.85 ± 1.67	0	0
T. tabaci			
Adults	1.13 ± 0.33a	12.83 ± 5.41b	25.72 ± 5.99c
Larvae	1.14 ± 0.26	0	0

[a]Adult means within a row followed by different letters were significantly different at $P < 0.01$ based on Tukey HSD tests.

more adults than yellow traps, while the traps consistently collected more adults than found on plants (Fig. 2, Table 1), indicating the traps are very sensitive and could function as an early warning of thrip activity. Comparison of the entire plot catches by trapping date (Fig. 2) indicates the traps did not predict thrip populations on plants during the season. In addition, correlation analyses by date were not significant.

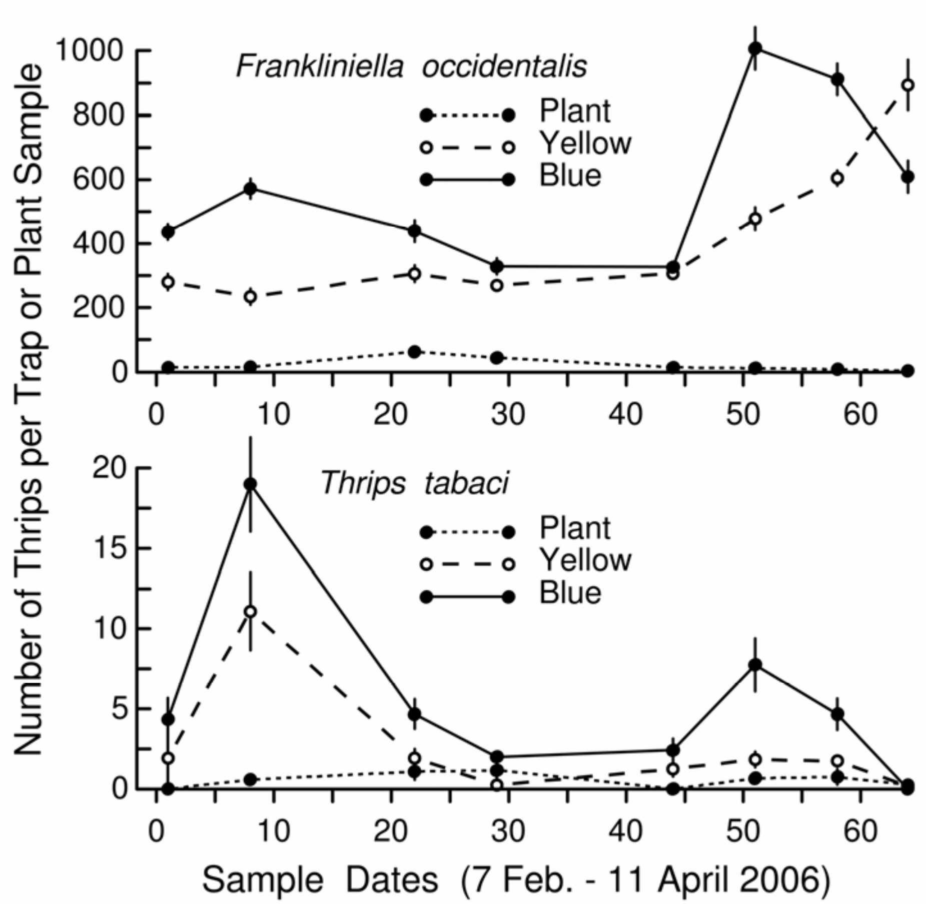

FIG. 2. Mean numbers (± SE) of *Frankliniella occidentalis* and *Thrips tabaci* adults collected per week on yellow and blue sticky traps compared to five lettuce plants from 7 February to 11 April 2006 at Holtville, CA.

However, comparison of traps with plants within all replicates (plants and nearby traps in each block, N = 96) indicated a significant negative correlation between thrip populations on plants and blue trap catch (r = -0.41, P < 0.001) as well as yellow trap catch (r = -0.42, P < 0.001). These negative correlations could arise if some of the colored traps attracted adult thrips from adjacent plants as well as dispersing individuals so they did not land on the nearby lettuce plants, thereby reducing populations on plants and inflating some trap catches. In contrast, similar analysis showed a significant positive correlation for adult *F. occidentalis* and larvae on plants (r = 0.37, P < 0.001), as well as adults caught on blue versus yellow traps within replicate blocks (r = 0.45, P < 0.001).

More adult *T. tabaci* also were captured on blue traps compared to yellow traps in lettuce plots (Table 1, Fig. 2). No *T. tabaci* larvae were found on either blue or yellow traps. The mean number of adult *T. tabaci* captured on blue traps (5.6) was 10 times the numbers recovered from the whole plant samples. A few *T. tabaci* larvae were found on plants, but none on blue and yellow traps in lettuce plots. Again, the blue traps on average caught more than the yellow traps, while both colors usually collected more adults than the plants (Fig. 2, Table 1). The blue traps were more sensitive in detection of *T. tabaci* than plant sampling since in 61 replicates, no adult *T. tabaci* were observed on plant samples while one or more adults were caught on the blue trap (these blue traps averaged 6.8/trap). Comparison of the entire plot catches on traps with numbers on plants (Fig. 2) indicates the traps did not predict *T. tabaci* populations on plants in the plot (and correlations were not significant). Furthermore, comparisons of plants with the nearest traps within replicates (N = 96) also did not indicate any significant correlations between plant population and blue trap catch or yellow trap catch, possibly due to the lower numbers collected. However, similar analysis showed a significant positive correlation for adult *T. tabaci* and larvae on plants (r = 0.28, P = 0.005), as well as adults caught on blue versus yellow traps (r = 0.51, P < 0.001).

More adult *F. occidentalis* were captured on blue traps compared with yellow traps in onion plots (Table 1). No *F. occidentalis* larvae were captured on blue or yellow traps. The average number of adult *F. occidentalis* captured on the blue trap per week (614) was 61 times the average found on five whole plant samples. The blue traps usually caught more adults than yellow traps, and the traps consistently collected more adults than found on plants (Fig. 3, Table 1), again suggesting the traps were sensitive for monitoring dispersal of *F. occidentalis* in onion fields. Comparison of the entire plot catches by trapping date (Fig. 3) indicates the traps did not predict plant populations during the period. In addition, correlation analyses by date were not significant. In contrast to results in lettuce, comparison of traps with

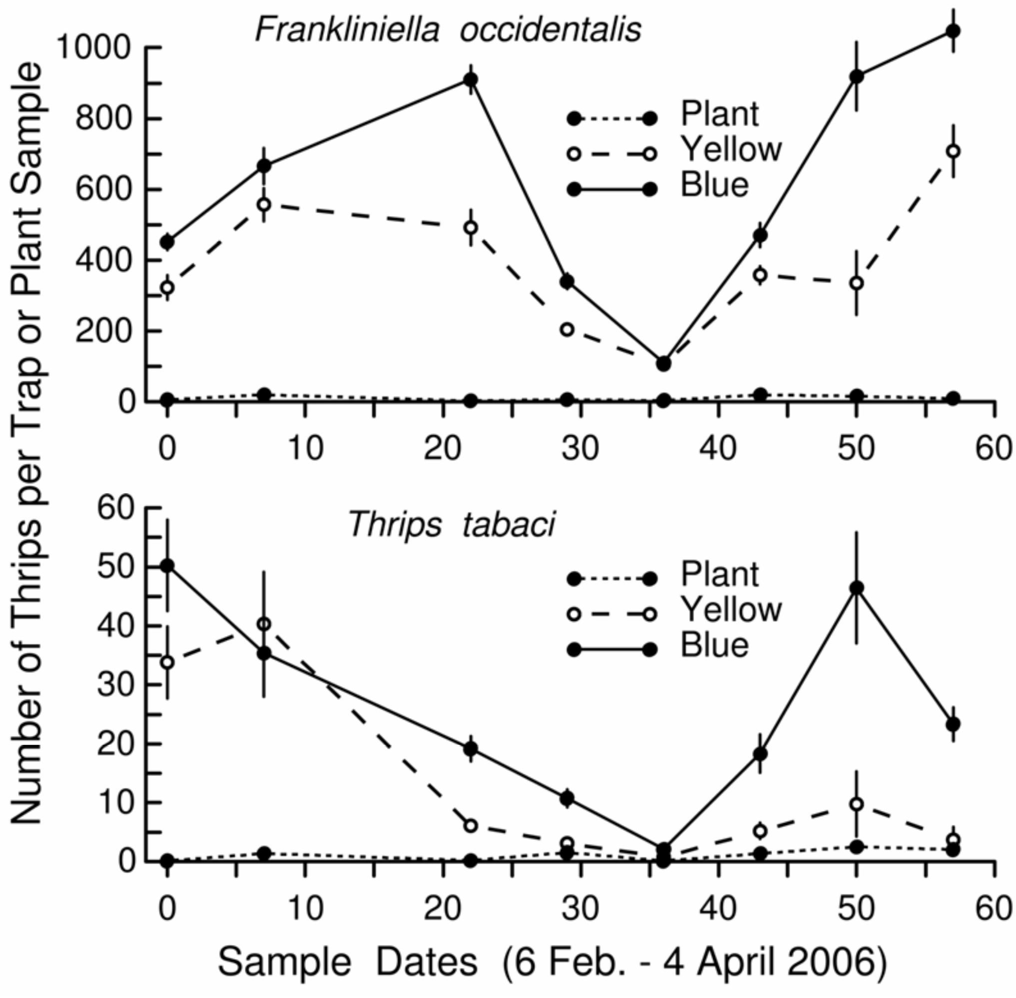

FIG. 3. Mean numbers (± SE) of *Frankliniella occidentalis* and *Thrips tabaci* adults collected per week on yellow and blue sticky traps compared to five onion plants from 6 February to 4 April 2006 at Brawley, CA.

onion plants within all replicates (N = 96) did not give a significant correlation between plant population and trap catch of either color. There also were no significant correlations between number of adults and larvae of *F. occidentalis* on onion; however, there was a significant positive correlation between the catches on the two trap colors ($r = 0.42$, $P < 0.001$).

More adult *T. tabaci* also were captured on blue traps compared to yellow traps in onion plots (Table 2, Fig. 3). No *T. tabaci* larvae were found on blue or yellow traps. A few *T. tabaci* larvae were found on plants, but none on blue and yellow traps. The average number of adult *T. tabaci* captured on the blue trap per week (26) was 23 times the average found on the five whole plant samples. The blue traps usually caught more adults than yellow traps, and the traps consistently collected more adults than found on plants (Fig. 3). Of 41 replicates where no adult *T. tabaci* were observed on plant samples, but one or more adults were caught on the blue trap, the blue traps caught 1,136 adults (mean of 27.7/trap). These results again suggest the traps were sensitive for monitoring dispersal of *T. tabaci* in onion fields. Comparison of the entire plot catches by trapping date (Fig. 3) indicates the traps did not predict plant populations during the period and correlation analyses by date were not significant. As with lettuce, there was no significant correlation between numbers on traps of either color and onion plants within all replicates (N = 96). There was a significant correlation between number of adults and larvae of *T. tabaci* on onion plants ($r = 0.35$, $P = 0.001$). As with the other thrip species, there was a positive correlation between the catches on the two trap colors for *T. tabaci* ($r = 0.24$, $P = 0.019$), but this was not significant due to a correction for multiple comparisons ($\alpha = 0.006$).

A positive correlation between trap catch and plant populations is expected if thrips encounter traps in proportion to populations on plants. Except for *F. occidentalis* in lettuce, the lack of significant correlations between thrip numbers caught on yellow and blue traps versus whole plants in the vicinity can be explained by a high variation in flight densities and plant populations within the plots over time. However, the numbers of thrips on traps did not vary greatly among the 12 plots each week as evidenced by relatively small standard errors of the means (Figs. 2, 3). Little is known about the dispersal behavior of thrips species, although *F. occidentalis* males form swarming leks in the morning that females visit to find mates (Matteson and Terry 1992). Recently, *F. occidentalis* has been shown to have a male-produced sex pheromone consisting of two major components, (R)-lavandulyl acetate and neryl (S)-2-methylbutanoate (Hamilton et al. 2005). The colored traps should catch thrips in proportion to their flight densities averaged throughout the week, while landing behavior could occur at different times or for shorter periods and thus contribute to a lack of correlation. The weekly catches of thrips on the colored traps relative to the measured adult populations on plants (Figs. 2, 3) indicate that thrip behavior changes over the season since the attraction and/or host settling ratio differed over the course of several weeks, probably depending on population age structure and host plant physiology.

No significant positive correlations were found between trap catch and thrip populations on plants in either thrip species; rather, a significant negative correlation was observed for *F. occidentalis* in lettuce that suggests some thrips may have left the plants and were caught on the nearest traps. This hypothesis is supported by repeated simulation of 96 pairs of random numbers of thrips on the *plant* and *trap* that were uncorrelated 95% of the time, as expected. However, when half the data pairs were treated such that random proportions of the thrip numbers on the *plant* were removed and random proportions of thrips on the *trap* were added, then significant negative correlations were usually observed. Mass trapping of the population could have occurred since an average of 6,942 *F. occidentalis* were caught on the 12 blue traps each week compared to an estimated population on lettuce of 4,039 (Table 1, 22.44 x 75 / 5 x 12). Therefore, the blue and yellow traps caught approximately 43.3% and 31.5%, respectively, of the known thrips in the lettuce crop. These are maximum estimates because the traps also could capture immigrating thrips. Further support that mass trapping occurred was that the thrip populations on plants remained consistently low throughout the two-month period and never reached densities requiring control treatments, indicating the colored traps continually removed significant numbers of the reproductive adults. Future work on measuring an effective attraction radius of the colored traps is needed to determine if higher densities of traps would be cost effective for successful control by mass trapping (Byers et al. 1989, El-Sayed et al. 2006, Byers 2007).

Sticky traps of different colors have been used for sampling and monitoring or controlling thrips in greenhouses (Roditakis et al. 2001). Blue traps captured significantly more *F. occidentalis* adults than yellow traps in lettuce and onions in our studies. These results agree with earlier reports (Matteson and Terry 1992, Chu et al. 2000, Roditakis et al. 2001, Chen et al. 2004, Chu et al. 2006). In contrast, Teulon and Brown (1992), Jenser et al. (2001), and Al-Ayedh and Al-Doghairi (2004) reported that yellow traps captured more *T. tabaci* than blue traps in greenhouses. Results of our studies suggest the need for experiments with blue traps of larger size to explore whether it is possible to reduce thrips populations by means of mass trapping. Blue traps in combination with sex pheromone may further enhance the potential of mass trapping.

To determine the need for control of thrips in an area, Palumbo (1998) recommends that (1) plant parts be carefully examined for thrips and feeding scars, (2) sticky traps be placed on field margins to indicate when adults disperse from adjacent vegetation, and (3) plant sampling be done that dislodges thrips onto surfaces where they can be counted and identified. University of California Pest Management Guidelines for thrips sampling on onion crops suggests random samples of at least five whole onion plants. A threshold of 30 thrips per plant in mid-season (lower for very young plants and higher for larger mature plants) has been used successfully to control thrips for dry bulb fresh market and drying onions. For processing onions, ten whole plant samples from four areas of the field are recommended. Weekly sampling is suggested when counts exceed 20 thrips per plant on two successive sample dates. Cumulative thrips-days of 500 to 600 during crop growth are estimated to cause significant yield loss. This is the equivalent of 50 to 60 thrips per plant per day for 10 days, or 25 to 30 thrips per plant per day for 20 days (Coviello et al. 2005).

Results from our study indicate that blue traps could be used as an early detection tool with minimal effort that would be more sensitive than costly and time-consuming plant sampling. Thus, until thrips were detected on traps no plant sampling would be needed. Once traps detected thrips plant sampling would be initiated to determine when thresholds for IPM treatments of thrips had been reached in lettuce and onions. The same thresholds can be used in synchronous areawide IPM programs that in models had less cumulative thrips-days and required less frequent treatments than did traditional asynchronous IPM (Byers and Castle 2005). Our results also indicate that blue traps by themselves may trap significant portions of thrip populations, and thus further work is needed to explore the potential for control, especially in conjunction with sex pheromone.

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References Cited

Al-Ayedh, H., and M. Al-Doghairi. 2004. Trapping efficiency of various colored traps for insects in cucumber crop under greenhouse conditions in Riyadh, Saudi Arabia. Pakistan J. Biol. Sci. 7: 1213-1216.

Briscoe, A. D., G. D. Bernard, A. S. Szeto, L. M. Nagy, and R. H. White. 2003. Not all butterfly eyes are created equal: Rhodopsin absorption spectra, molecular identification, and localization of ultraviolet-, blue-, and green-sensitive rhodopsin-encoding mRNSs in the retina of *Vanessa cardui*. J. Comp. Neurol. 458: 334-349.

Byers, J. A. 2006. Analysis of insect and plant colors in digital images using Java software on the Internet. Ann. Entomol. Soc. Amer. 99: 865-874.

Byers, J. A. 2007. Simulation of mating disruption and mass trapping with competitive attraction and camouflage. Environ. Entomol. in press

Byers, J. A., O. Anderbrant, and J. Löfqvist. 1989. Effective attraction radius: A method for comparing species attractants and determining densities of flying insects. J. Chem. Ecol. 15: 749-765.

Byers, J.A., and Castle, S.J. 2005. Areawide models comparing synchronous versus asynchronous treatments for control of dispersing insect pests. J. Econ. Entomol. 98: 1763-1773.

Campbell, L. R., K. L. Robb, and D. E. Ullman. 2006. The complete tospovirus database. www.oznet.ksu.edu/tospovirus/tospovirus_host_list_with_references.pdf

Chen, T-Y, C. C. Chu, G. Fitzgerald, E. T. Natwick, and T. J. Henneberry. 2004. Trap Evaluations for Thrips (Thysanoptera: Thripidae) and Hoverflies (Diptera: Syrphidae). Environ. Entomol. 33: 1446-1420.

Chittka, L. 1997. Bee color vision is optimal for coding flower color, but flower colors are not optimal for being coded – Why? Israel J. Plant Sci. 45: 115-127.

Chu, C. C., P. J. Pinter, Jr., T. J. Henneberry, K. Umeda, and E. T. Natwick. Y.-A. Wei, V. R. Reddy, and M. Shrepatis. 2000. Use of CC traps with different trap base colors for silverleaf whiteflies (Homoptera: Aleyrodidae), thrips (Thysanoptera: Thripidae), and Leafhoppers (Homoptera: Cicadellidae). J. Econ. Entomol. 93:1329-1337.

Chu, C. C., M. A. Ciomperlik, N.-T. Chang, M. Richards, and T. J. Henneberry. 2006. Developing and evaluating traps for monitoring Scirtothrips dorsalis (Thysanoptera: Thripidae). Florida Entomol. 89: 47-55.

Coviello, R. L., and M. E. McGriffen, Jr. 1995. Damage threshold for thrips on drying onions. Univ. Calif. Plant Protection Quarterly. 5: 2-4.

Coviello, R. L., W. E. Chaney, and S. Orloff. 2005. Onion and garlic thrips. UC IPM Pest Management Guidelines: Onion and Garlic UC ANR Publication 3453. http://www.ipm.ucdavis.edu/PMG/r584300111.html

El-Sayed, A. M, Suckling, D. M, Wearing, C. H., and Byers, J. A. 2006. Potential of mass trapping for long-term pest management and eradication of invasive species. J. Econ. Entomol. 99:1550-1564.

Hamilton, J. G. C., D. R. Hall, and W. D. J. Kirk. 2005. Identification of a male-produced aggregation pheromone in the western flower thrips *Frankliniella occidentalis*. J. Chem. Ecol. 31: 1369-1379.

Jenser, G., A. Szenasi, and J. Zana. 2001. Investigation on the colour preference of *Thrips tabaci* Lindeman (Thysanoptera: Thripidae). Acta Phytopathol. Entomol. Hungarica 36: 207-211.

Kevan, P. G., L. Chittka, and A. G. Dyer. 2001. Limits to the salience of ultraviolet: lessons from colour vision in bees and birds. J. Exp. Biol. 204: 2571-2580.

Laughlin, S. B. 1976. The sensitivities of dragonfly photoreceptors and the voltage gain of transduction. J. Comp. Physiol. 111: 221-247.

Liu, T.-X., and C. C. Chu. 2004. Comparison of absolute estimates of *Thrips tabaci* ((Thysanoptera: Thripidae) with field visual counting and sticky traps in onion field in south Texas. Southwest. Entomol. 29: 83-89.

Matteson, N., and I. Terry. 1992. Response to color by male and female *Frankliniella occidentalis* during swarming and non-swarming behavior. Entomol. Exper. Appl. 63: 187-201.

Meister, H. S., E. T. Natwick, T. A. Turini, K. M. Turini, J. N. Guerrero, and K. Mayberry. 2004. Guidelines to production costs and practices for Imperial County 2004-2005 vegetable crops. 83 pages, Imperial County Circular 104-V.

Menzel, R., and M. Blakers. 1976. Colour receptors in the bee eye – Morphology and spectral sensitivity. J. Comp. Physiol. 108: 11-33.

Mound, L. A. (2005). Thysanoptera: Diversity and interactions. Ann. Rev. Entomol. 50: 247-269.

Natwick, E. T., W. E. Chaney, and N. C. Toscano. 2002. Insects and other arthropods. In: UC IPM Pest Management Guidelines: Lettuce. UC ANR Publication 3450. http://www.ipm.ucdavis.edu/PMG/selectnewpest.lettuce.html

Palumbo, J. C. 1998. Management of aphids and thrips on leafy vegetables. 1998 Vegetable Report University of Arizona publication AZ1101. http://ag.arizona.edu/pubs/crops/az1101/az1101_2.html

Palumbo, J., A. Fournier, P. Ellsworth, K. Nolte, and P. Clay. 2006. Insect crop losses and insecticide usage for head lettuce in Arizona: 2004-2006. University of Arizona publication, AZ.

Roditakis, N. E., D. P. Lykouressis, and N. G. Golfinopoulou. 2001. Color preference, sticky trap catches and distribution of western flower thrips in greenhouse cucumber, sweet pepper and eggplant crops. Southwest. Entomol. 26: 227-238.

Sherwood, J. 2005. Topoviruses in Solanaceae and other crops in the coastal plain of Georgia. Georgia College of Agriculture and Environmental Science Res. Rep. No. 704.

Sokal, R. R., and Rohlf, F. J. 1995. Biometry. W. H. Freeman and Company, New York.

Teulon, A. J., and D. R. Brown. 1992. Colour preferences of New Zealand thrips (Terebrantia: Thysanoptera), New Zealand Entomol. 8-13.

Thrips knowledge base. 2006. Retrieved on Oct. 24 from http://www.gladescropcare/wfthp.html.