Seasonal Abundance and the Use of an Action Threshold for Western Flower Thrips, in a Cut Carnation Greenhouse

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Additional index words. greenhouse production, scouting, damage threshold, insecticides, cut flowers, *Frankliniella occidentalis*, *Dianthus caryophyllus*

Summary. A 2-year greenhouse study was conducted to evaluate the seasonal population dynamics and use of an action threshold for western flower thrips *(Frankliniella occidentalis)* in cut carnation (*Dianthus caryophyllus*). An action threshold of 20 thrips/card/week was adopted to time insecticide applications. The highest numbers of thrips were caught on blue-colored sticky cards from May through September whereas the lowest thrips numbers were present from November through March 1994 and 1995. Thrips numbers based on sticky card counts, from December through March for both years were below the action threshold and as a result, no insecticides were applied. Thrips abundance on blue sticky cards was significantly correlated with both numbers of thrips in flowers and a subjective ranking of flower quality. Seasonal patterns of both insecticide use and numbers of damaged flowers closely followed patterns of thrips abundance found on blue sticky cards. Our findings are the first to demonstrate, based on a case study over a 2-year period, that routinely scouting for thrips throughout the year can lead to fewer insecticide applications and thus possible cost savings in labor and insecticide purchases. This study suggests that sticky cards can be an effective tool for reducing insecticide applications in regions of the U.S. where there are seasonal fluctuations of thrips abundance.

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Western flower thrips (Thysanoptera: Thripidae), are a major pest of greenhouse-grown floriculture crops. Thrips cause direct damage by feeding on foliage and flowers, and indirect damage by transmitting the tospoviruses tomato spotted wilt and impatiens necrotic spot virus (Allen and Broadbent, 1986; DeAngelis et al., 1993). Both thrips and viruses have a broad host range (MacDonald, 1993). As a result, there is a very low tolerance for the presence of thrips in most commercial greenhouses. However, the level of thrips tolerance may vary with the crop production system (Brodsgaard, 1993). In the absence of any disease, crops grown for their foliage and flowers have a much higher tolerance for thrips numbers compared with crops grown primarily for the flowers, because thrips damage to flowers is the main concern. Similarly, greenhouse-grown vegetables, such as pepper (*Capsicum annuum*), have a higher tolerance for thrips because they are grown for the fruit, which is less susceptible to thrips injury (Hsu and Quarles, 1995). Tolerance of thrips populations allows greenhouse producers to structure their pest management program around changes in pest numbers rather than reacting to the simple detection of pests.

Monitoring with colored sticky cards is commonly recommended to help greenhouse producers track increases and declines in pest populations throughout the growing season (Binns and Nyrop, 1992; Shipp and Zariffa, 1990) and to assess which management strategies are providing control (Cloyd and Sadof, 1998; Heinz et al., 1992; Parrella, 1992). Using sticky cards can also help growers to determine the spatial distribution of a pest, identify portions of fields or greenhouse ranges where pests are present, and target localized populations of pests with insecticides (Parrella, 1992; Pearsall and Myers, 2001). A pattern of localized applications might slow the onset of insecticide resistance, a problem that has been particularly troublesome in the management of western flower thrips (Robb et al., 1995).

Although greenhouses are capable of harboring western flower thrips throughout the year, population increases may be fostered by warmer temperatures and longer daylengths (Brodsgaard, 1994; Sites and Chambers, 1990). Growers monitoring for western flower thrips should observe seasonal increases in thrips numbers in the spring and summer months. In temperate regions where daylength and temperature fluctuations are large, some growers may be able to identify times of the year when the seasonal abundance of western flower thrips tends to stay low and pest management inputs, such as insecticides, are minimal thus possibly saving costs in labor and insecticide purchases. The objective of this study was to test this hypothesis by tracking the population dynamics of western flower thrips in a greenhouse over a 2-year period.

Materials and methods

This study was conducted in 1994 and 1995 at the Purdue University Horticulture and Landscape Architecture Department greenhouses, West Lafayette, Ind. The greenhouse dimensions were 11 m (36.1 ft) in length by 12 m (39.4 ft) in width, oriented north-south. The greenhouse contained five upright soil benches 10 m (32.8 ft) in length by 2 m (6.6 ft) in width, and 15 cm (5.9 inches) in depth. An existing crop of intermixed red and white cut carnation was used for the study. The plants were grown under natural daylight conditions. Greenhouse temperatures throughout the year ranged from 15.6 to 23.9 °C (±1.7 °C) [60 to 75 °F (±3 °F)] with a relative humidity between 60 to 70%. The growing medium in the soil benches consisted of 50% soil, 25% perlite, and 25% vermiculite. Blue sticky cards [8 × 13 cm (3.1 × 5.1 inches)] (Hummert International, Earth City, Mo.) were used to monitor for adult western flower thrips. We chose blue sticky cards for our study because they have been shown to be highly attractive to adult western flower thrips (Brodsgaard, 1989). Sticky cards were placed approximately 5 to 8 cm (2.0 to 3.1 inches) above the crop canopy, where thrips are most active (Gillespie and Vernon, 1990). Two sticky cards were used on each of five benches in the greenhouse. Western flower thrips adults were counted on fresh sticky cards replaced weekly during winter and twice weekly in late spring, summer, and fall. To determine whether the average weekly catch in the greenhouse was above a 20 thrips/card threshold, we prorated the counts of individual cards collected by multiplying the average daily card catch by seven.

Populations of adults and immature thrips on flowers were estimated from a sample of two randomly selected open flowers on each of the five benches. The greenhouse assistant was the individual responsible for scouting and would blow into each selected flower to count the number of thrips present in the open blooms and assess thrips flower injury (petal distortion). Less than one minute was spent for each flower. Blooms were considered acceptable or unacceptable based on a subjective evaluation. Flower injury was subjectively quantified using a numerical rating scale that ranged from 1 to 5 [1 = no visible injury, 2 = up to 25% petal distortion, 3 = up to 50% petal distortion, 4 = up to 75% petal distortion, and 5 = over 75% petal distortion]. All scouting information was recorded in a Microsoft Excel database system.

The following insecticides and rates were used during the 24-month study when thrips numbers exceeded the action threshold: abamectin (Avid; Syngenta, Greensboro, N.C.) at 0.39 mL·L^{-1} (5.0 fl oz/100 gal); abamectin at 0.39 mL·L^{-1} plus bendiocarb (Turcam; Aventis Environmental Sciences, Montvale, N.J.) at 560 mg·L^{-1} (ppm) (7.5 oz/100 gal); formetanate (Carzol; Aventis Environmental Sciences) at 750 mg·L^{-1} (10.0 oz/100 gal); chlorpyrifos (Dursban; Dow AgroSciences, Indianapolis, Ind.) at 600 mg·L^{-1} (8.0 oz/100 gal); chlorpyrifos-microencapsulated (Duraguard; Whitmire Micro-Gen Research Labs, Inc., St. Louis, Mo.) at 2.3 mL·L^{-1} (30.0 fl oz/100 gal); methomyl (Lannate; DuPont Agricultural Products, Wilmington, Del.) at 1.17 mL·L^{-1} (15.0 fl oz/100 gal); acephate (Orthene; Valent USA Corporation, Walnut Creek, Calif.) at 562 mg·L^{-1} (7.5 oz/100 gal); acephate at 937 mg·L^{-1} (12.5 oz/100 gal) plus kinoprene (Enstar II; Wellmark International, Bensenville, Ill.) at 0.58 mL·L^{-1} (7.5 fl oz/100 gal); acephate at 562 mg·L^{-1} (7.5 oz/100 gal) plus fenpropathrin (Tame; Valent USA Corporation) at 0.98 mL·L^{-1} (12.5 fl oz/100 gal); and bifenthrin (Talstar; FMC Turf & Ornamentals, Philadelphia, Pa.) at 1.17 mL·L^{-1} (15.0 fl oz/100 gal). All insecticide applications were made with a hydraulic high-volume power sprayer. No insecticide was used continuously for more than two weeks.

Although carnation flowers were harvested periodically during the study, there was always a continuous supply of flowers all-year long, and the plant population was maintained at a relatively consistent level.

Relationships among average estimates of thrips populations in flowers, card catches, and flower damage ranking on each sampling date were assessed by Pearson's correlation coefficient (PROC CORR) (SAS Institute, 2002).

Results and discussion

In our study, the numbers of western flower thrips were highest from May through September for both 1994 and 1995 (Fig. 1). This is similar to the seasonal pattern of thrips observed in other cropping systems (Brodsgaard, 1993; Frey, 1993; Pearsall and Meyers, 2001), and is most likely due to the higher reproduction rate and faster development time at high summer temperatures (Lublinkhof and Foster, 1977). This may also be the reason why the insecticide applications were not able to prevent flower injury from occurring despite two to three insecticide applications per week during the summer months. However, scouting for thrips using the blue sticky cards allowed us to identify December through March as a time year when weekly populations were below 20 thrips/card and as a result, no insecticides were applied (Fig. 2). This suggests that greenhouse producers don't need to use insecticides continuously

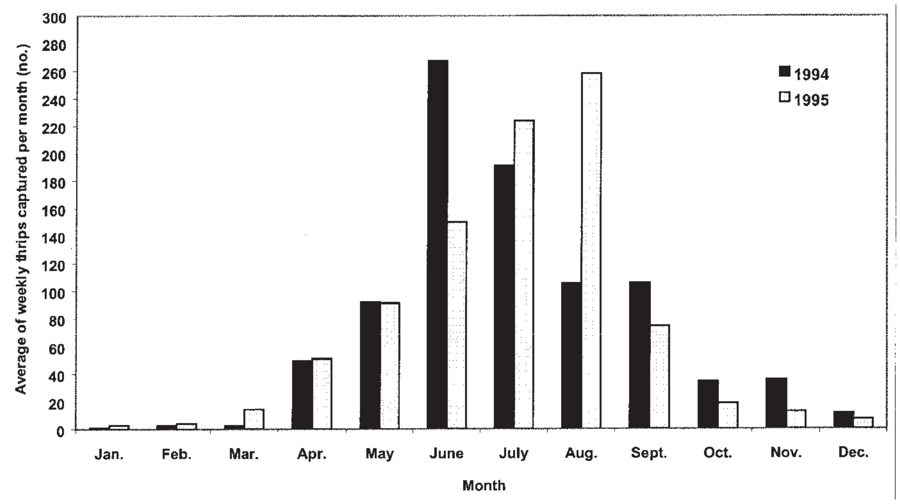

Fig. 1. Mean of weekly western flower thrips adults captured on blue sticky cards per month in a cut carnation greenhouse for 1994 and 1995.

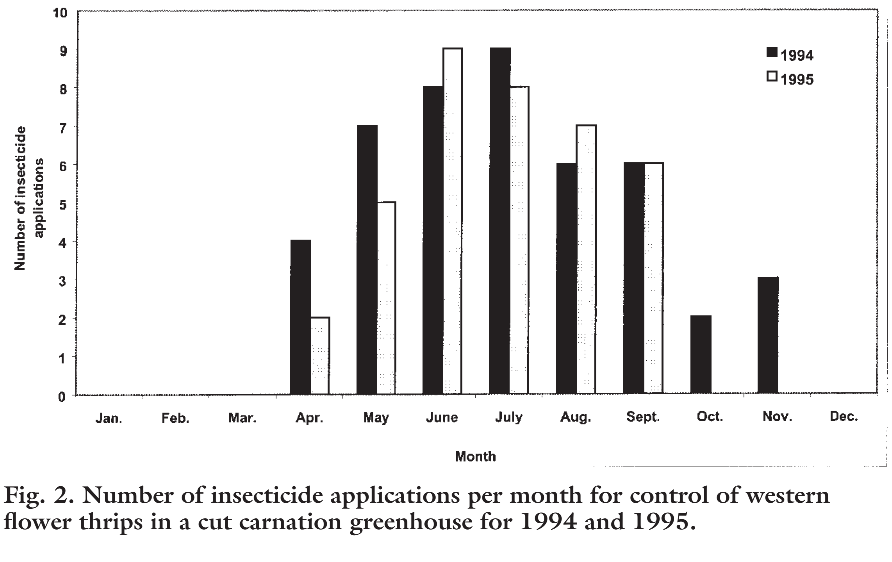

Fig. 2. Number of insecticide applications per month for control of western flower thrips in a cut carnation greenhouse for 1994 and 1995.

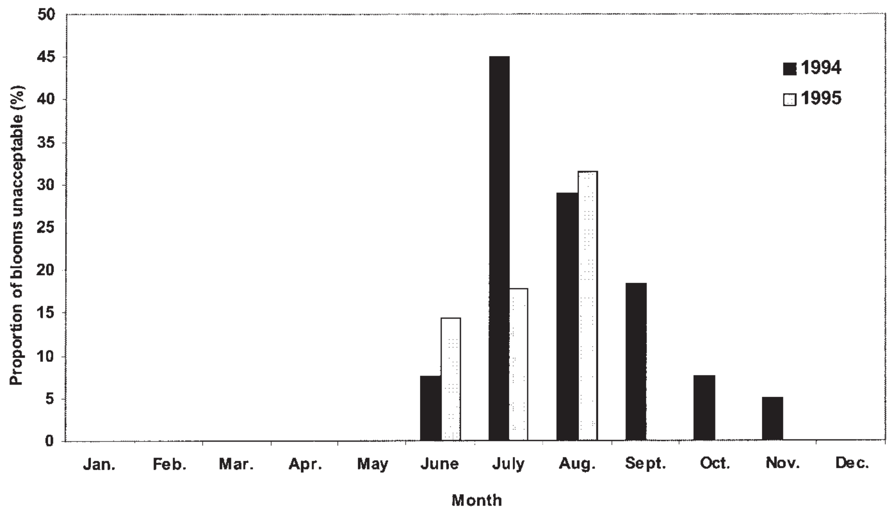

Fig. 3. Unacceptable blooms (>25% distortion) produced per month with a weekly sticky card threshold of 20 western flower thrips in a cut carnation greenhouse for 1994 and 1995.

during the year, as thrips numbers may be low enough during certain times that sprays are not warranted. This then lowers worker exposure to insecticide residues and possible allergic reactions, reduces environmental contamination, decreases labor costs associated with making applications, prevents possible flower injury (phytotoxicity), and may even lessen the potential for thrips populations to develop resistance to insecticides (Nyrop et al. 1999).

Over the course of the study, the number of unacceptable blooms (with >25% petal distortion) was greatest during the months when western flower thrips were most abundant (Figure 3). Although we did not determine whether consumers will tolerate up to 25% distortion in carnations, other studies have reported public tolerances of between 20% to 25% petal distortion on chrysanthemum blooms (Sadof and Sclar, 2002).

The seasonal periodicity of estimates of thrips abundance and flower damage (Figs. 1 and 3) suggests that these measures should be correlated. This hypothesis is generally supported by our correlation analyses. In 1994 and 1995, the daily estimate of thrips caught on cards was significantly correlated with estimates of thrips in flowers (1994: $r = 0.40$, n = 59, $P = 0.0016$; 1995: $r = 0.73$, df = 74, $P < 0.0001$) and with the rank of flower damage (1994: $r = 0.40$, n = 59, $P = 0.0016$; 1995: $r = 0.47$, n = 74, $P < 0.001$). Thrips counts per flower, however, were not correlated with rank of flower damage in 1994 ($r = 0.11$, n = 59, $P = 0.41$), but they were correlated in 1995 ($r = 0.36$, n = 74, $P = 0.0016$). This inconsistency across years suggests a weak relationship between our estimates of thrips numbers per flower and flower damage.

Sticky cards provide a coarse measure of thrips populations that can be used to identify times of year when thrips must be managed intensively. The threshold value of 20 thrips/card/week appeared to be adequate for these purposes. Furthermore, our findings support the arbitrary action threshold of 10 to 20 thrips per sticky card per week to time insecticide applications (Daughtrey et al., 1995). However, the abundance of damaged flowers in the summer months indicates that some refinements are needed during the times of year when thrips populations are most active and likely to damage flowers in the greenhouse. Other studies have indicated that sampling open blooms for adult western flower thrips provides better information and may be more cost effective for making management decisions when thrips are abundant (Shipp and Zariffa, 1991).

Our findings show that maintaining detailed records and assessing population trends are important in making fact-based pest management decisions on when to apply insecticides (Wawrzynski et al., 2001). In addition, this may allow greenhouse producers to incorporate the use of biological control agents such as parasitoids and/or predators into their pest management programs (Nyrop et al., 1999). There is minimal information available to greenhouse producers to associate scouting with a reduction in insecticide use and greenhouse producers need to identify reasons to justify the costs of scouting whether it is hiring a professional scout or designating an employee. This case study over a 2-year period is the first to demonstrate that routinely scouting for thrips throughout the year can lead to fewer insecticide applications and thus possible cost savings in labor and insecticide purchases.

In conclusion, despite their limitations, sticky cards are likely to increase greenhouse producer adoption of integrated pest management practices by engaging them in a process that helps them identify times of the year when insecticide use is not required for thrips management.

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Evaluation of Five Methods for Estimating Class A Pan Evaporation in a Humid Climate

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ADDITIONAL INDEX WORDS. irrigation scheduling

SUMMARY. Evaporation pans continue to be used extensively throughout the world to measure free-surface water evaporation (E_{pan}) and to estimate evapotranspiration for irrigation scheduling and water management for agronomic and horticultural crops. E_{pan} is also being used extensively to estimate evaporation rates from lakes, wetlands, rivers, reservoirs, and other water bodies for management of wildlife and ecological habitat. A reliable method is needed to estimate missing daily E_{pan} data. Determination of a reliable method for the estimation of E_{pan} would also be useful in modeling of crop growth, and hydrological and ecological systems. Five methods [Penman (Penman, 1948), Kohler-Nordenson-Fox (KNF) (Kohler et al., 1955), Christiansen (Christiansen, 1968), Priestley-Taylor (PT) (Priestley and Taylor, 1972), and Linacre (Linacre, 1977)] for estimating E_{pan} were compared with the historical (23-year) measured daily values to determine the success of accurate and consistent E_{pan} estimations under humid climatic conditions in Florida. The root mean square error (RMSE) was used as the criteria to judge the accuracy and reliability of a given method. An RMSE value of <0.5 mm·d^{-1} (0.02 inches/d) between the measured and estimated E_{pan} was considered as an acceptable error for daily estimations. The standard deviation (SD) values, and percent error (%E) between the estimated and measured values were

Florida Agricultural Experiment Station journal series R-07895.

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